SaskAuto

Daytime Running Lights Reduce Accidents – A Two Year Fleet Experience in Saskatchewan

AN ANALYSIS OF THE USE OF DAYTIME RUNNING LIGHTS IN THE CVA FLEET IN SASKATCHEWAN

Prepared for

Traffic Safety Services Department
SaskAuto

Prepared by

Gordon A. Sparks
and
Russell D. Neudorf
Clayton, Sparks & Associates Ltd.
Saskatoon, Saskatchewan

in Association with

Anne E. Smith
Decision Focus Incorporated
Los Altos, California

January 1989

89-06089/

EXECUTIVE SUMMARY

During the summer of 1986, Saskatchewan Government Insurance installed automatic daytime running light devices (DRL's) on 4000 vehicles owned by the Provincial Central Vehicle Agency (CVA), Government of Saskatchewan. These devices automatically turn on (off) the low beam headlights and the parking lights when the ignition is turned on (off). The objective of this study was to assess the effect that the use of daytime running lights have had on the accident experience of the CVA vehicle fleet in terms of the number and severity of accidents. The information used in this study was obtained from the Traffic Accident Information System (TAIS) database, maintained by Saskatchewan Highways and Transportation.

The accident experience of the CVA vehicle fleet was studied over a period of eight years (ie. 1980 to 1987). This involved six years of data prior to the installation of the DRL devices (pre-DRL's) and two years of data after the installation of the DRL devices (post-DRL's). The accident experience information, obtained from the TAIS database, was first summarized by total number of accidents by year. In reviewing the data, it was noted that the definition of a reportable accident (and hence one that would be entered into the TAIS database) had been redefined at the start of 1984 from one involving more than $200 damages to one involving more than $500 damages. In order to keep the data

consistent from year to year, only accidents with damages of more than $500 were used in the analysis.

Through a systematic breakdown of the total accidents with damages greater than $500, a profile of the accidents that would be affected by the use of DRL's, namely multiple-vehicle daylight accidents, was obtained. This profile classified the DRL related accidents by number, by severity, by cost, and by accident configuration. It was on this accident profile that a detailed statistical analysis was conducted.

The statistical analysis involved a difference of means test using the normal distribution (Z-statistic). The accident experience pre-DRL's and post-DRL's was compared and the actual percent difference and statistical significance of the observed differences were calculated.

The statistical analysis indicates that the total number of multiple-vehicle daylight accidents per year decreased by 11.6% from the pre-DRL period to the post-DRL period. This decrease was statistically significant at the 99.9% confidence level.

This decrease in multiple-vehicle daylight accidents translates into an estimated 7.9% decrease in the total number of CVA accidents with damages greater than $500.

Over the same period of time as noted above, the total number of non-DRL affected accidents, namely all single vehicle accidents and multiple-vehicle darkness accidents, remained relatively constant with a decrease of only 0.3% (not statistically significant).

Multiple-vehicle daylight accidents were further classified by severity into three groups: property damage, personal injury, and fatality. A decrease was observed in all three catagories. Property damage accidents decreased by 10.1% (99.9% confidence level) and personal injury accidents decreased by 16.9% (95.3% confidence level). While there was an apparent decrease in fatalities (ie. 75%), the number of these events are insufficient to provide a high level of confidence (ie. the confidence level was only 93.7% because of a limited sample size).

Multiple-vehicle daylight accidents were also classified by accident configuration into two groups; those that would not be affected by the use of DRL's (non-DRL affected) and those accidents that would be affected by the use of DRL's (DRL-affected). Over the study period, the DRL-affected accidents decreased by 25.1% (99.9% confidence level) from the pre-DRL period to the post-DRL period. The same analysis for the non-DRL affected accidents showed only a 0.7% decrease (not statistically significant).

The data on multiple-vehicle daylight accident costs as estimated by police at the accident scene (both total and average) showed an increasing trend in the data from the pre-DRL period to the post-DRL period, despite the reduced accident numbers. This fact was attributed to a general increase in accident repair costs.

The results of this study indicate that daytime running lights have had a positive, statistically significant impact on the number of multiple-vehicle daylight accidents in the CVA vehicle fleet. It is expected that a comparable positive impact would be observed in the total Saskatchewan vehicle population in terms of reductions in accidents with the increased use of daytime running lights.

TABLE OF CONTENTS

1.0 Introduction 1
- 1.1 Background 1
- 1.2 Study Objectives 2
- 1.3 Study Scope 2

2.0 Background Statement 3
- 2.1 Concept of Daytime Running Light Use 3
- 2.2 Detailed Review of Actual Fleet Studies 4
  - 2.2.1 Effects on Accidents of Compulsory Use of Running Lights During Daylight in Sweden 4
  - 2.2.2 The Effect of Recommended and Compulsory Use of Vehicle Lighting on Road Accidents in Finland 5
  - 2.2.3 Fleet Experience with Daytime Running Lights in USA 7
  - 2.2.4 Summary Table of Fleet Studies 7
- 2.3 Important Issues Related to DRL Study 10

3.0 Profile of CVA Fleet Accident Experience 11
- 3.1 Introduction 11
- 3.2 Exposure of the CVA Fleet 14
- 3.3 Profile of Total Accidents 14
- 3.4 Profile of Accidents with Damages of More Than $500 19
- 3.5 Profile of Single and Multiple-Vehicle CVA Accidents 26
- 3.6 Profile of Multiple-Vehicle Accidents by Light Conditions 26
- 3.7 Profile of Multiple-Vehicle Daylight CVA Accidents by Configuration 37

4.0 Statistical Testing for Significant Differences 37
- 4.1 Statistical Approaches in Assessing the DRL Effect 37
  - 4.1.1 A Controlled Experiment 37
  - 4.1.2 A Sampling Procedure to Assess the DRL Effect 57
- 4.2 Statistical Testing Using A Time-Series Approach 59
  - 4.2.1 Difference of Means Test 59
  - 4.2.2 Probability of Detecting Statistically Significant Results 62
  - 4.2.3 Regressive Analysis 65
- 4.3 Results of the Statistical Tests 66
  - 4.3.1 Difference of Means Tests 66

5.0 Conclusions and Recommendations 70

Appendix A: Statistical Testing - Regression Analysis

Appendix B: Statistical Testing - Difference of Means Analysis

LIST OF TABLES

Table 1	Summary of Studies and Results	7-10
Table 2	Average Annual Distance per Vehicle in the CVA Fleet	14
Table 3	Total Number of CVA Accidents by Year	15
Table 4	Total Cost of CVA Accidents by Year	17
Table 5	Total Number of CVA Accidents by Severity	20
Table 6	Total Number of CVA Accidents Exceeding $500 in Damages by Year	22
Table 7	Total Cost of CVA Accidents by Year for Accidents with Damages Greater Than $500	24
Table 8	Number of CVA Accidents by Year by Accident Severity for Accidents with Damages Greater Than $500	27
Table 9	Total Number of Single and Multiple Vehicle CVA Accidents by Year for Accidents with Damages Exceeding $500	29
Table 10	Total Cost of Accidents for Single and Multiple Vehicle Accidents by Year for CVA Accidents with Damages Greater Than $500	31
Table 11	Number of Single and Multiple Vehicle Accidents by Year by Accident Severity for CVA Accidents with Damages Greater Than $500	33
Table 12	Number of Multiple Vehicle Accidents by Light Condition by Year for CVA Accidents with Damages Greater Than $500	35
Table 13	Total Cost of Multiple Vehicle CVA Accidents with Damages Greater Than $500 by Light Conditions by Year	38
Table 14	Number of CVA Accidents by Severity by Light Conditions by Year for Multiple Vehicle Accidents with Damages Greater Than $500	40
Table 15	Number of Multiple Vehicle, Daylight, CVA Accidents by Year by Configuration for Accidents with Damages Greater Than $500	42

Table 16	Total and Average Cost for Multiple Vehicle, Daylight, CVA Accidents by Year by Configuration for Accidents with Damages Greater Than $500	45
Table 17	Number of Multiple Vehicle Daylight CVA Accidents by Configuration, by Severity, by Year for Accidents with Damages Greater Than $500	48-49
Table 18	Total Cost of Multiple Vehicle Daylight CVA Accidents by Severity, by Year for Accidents with Damages Greater Than $500	54
Table 19	Number of CVA Accidents with Damages Greater Than $500	60
Table 20	Probability of Observing Significant Differences in Accident Levels Before and After DRL's on CVA Vehicles	65
Table 21	Summary of Statistical Analysis Difference of Means Test	67

LIST OF FIGURES

Figure 1	Components of the CVA Fleet Accident Profile	12
Figure 2	Total Number of CVA Accidents	16
Figure 3	Total Cost of CVA Accidents	18
Figure 4	Accident Severity, All CVA Accidents	21
Figure 5	Total Number of CVA Accidents Exceeding $500 in Damages	23
Figure 6	Total Costs of CVA Accidents Exceeding $500 in Damages	25
Figure 7	Accident Severity for CVA Accidents Exceeding $500 Damage	28
Figure 8	Single and Multiple Vehicle Accidents for CVA Accidents Exceeding $500 Damage	30
Figure 9	Total Cost of Accidents for CVA Accidents Exceeding $500 Damage	32
Figure 10	Accident Severity for CVA Accidents Exceeding $500 Damage	34
Figure 11	Number of CVA Accidents, Multiple Vehicle, Exceeding $500 Damage	36
Figure 12	Total Cost of CVA Accidents, Multiple Vehicle, Exceeding $500 Damage	39
Figure 13	Severity of CVA Accidents, Multiple Vehicle, Exceeding $500 Damage	41
Figure 14(A)	CVA Accidents by Configuration (DRL Affected) Multi Vehicle, Daylight, >$500 Damage	43
Figure 14(B)	CVA Accidents by Configuration (Non-DRL Affected) Multi Vehicle, Daylight, >$500 Damage	44
Figure 15(A)	CVA Accident Cost by Configuration (DRL Affected) Multi Vehicle, Daylight, >$500 Damage	46
Figure 15(B)	CVA Accident Cost by Configuration (Non-DRL Affected) Multi Vehicle, Daylight, >$500 Damage	47

Figure 16(A)	Accidents by Configuration and Severity (DRL Affected) Multiple Vehicle, Daylight, >$500 Damage	50
Figure 16(B)	Accidents by Configuration and Severity (DRL Affected) Multiple Vehicle, Daylight, >$500 Damage	51
Figure 16(C)	Accidents by Configuration and Severity (Non-DRL Affected) Multiple Vehicle, Daylight, >$500 Damage	52
Figure 16(D)	Accidents by Configuration and Severity (Non-DRL Affected) Multiple Vehicle, Daylight, >$500 Damage	53
Figure 17	Total CVA Accident Cost by Severity, Multiple Vehicle, Daylight >$500 Damage	55
Figure 18	Number of CVA Accidents with Damages >$500	61
Figure 19	Distribution of Differences of Means Hypothesis Testing	63
Figure 20	Distribution of Sample Outcomes	64

1.0 INTRODUCTION

1.1 BACKGROUND

One potential way of reducing both the number and severity of motor vehicle accidents is to use headlights during daylight operations. The use of headlights during daylight hours significantly increases the visibility of a vehicle which in turn intuitively would be expected to reduce the potential for vehicle accidents. This increased visibility would be expected to play a very important role, particularly under non-optimal lighting and/or driving conditions. For example, when drivers are heading into the sun on two lane, two way roadways either in the early morning or late evening periods, or during periods of inclement weather. The increased visibility would be expected to have a generally positive impact on both accident rates and accident severity in many other situations as well.

In the interest of promoting public safety, the Province of Saskatchewan has funded a campaign suggesting that the motoring public use their headlights during daytime operations. In addition, Saskatchewan Government Insurance has installed automatic daytime running light devices (DRL's) on approximately 4000 [1] vehicles operated by the Provincial Central Vehicle Agency (CVA). These devices will automatically turn on the vehicle lights when the vehicle is started and turn them off when the vehicle is stopped. (This device overcomes the problem of forgetting to turn the lights on when operating during daytime hours, as well as forgetting to turn them off when a trip is completed.)

As noted, running with the headlights on would intuitively be expected to reduce the number and severity of accidents. In fact, experiments and studies in other regions of the world have indicated a positive effect. There is however a need to quantitatively assess the impact that running with headlights on during daytime operations would have in the Saskatchewan setting. It is particularly important to scientifically establish that indeed running with headlights on during daylight periods does have a positive impact on accident rates and severity in Saskatchewan. Further, it would be highly desirable to specifically identify and quantify the benefits associated with wide use of headlights during daytime operations. Specific information of this nature could play an important role in

---

[1] There are a total of approximately 5400 vehicles in the CVA fleet. Approximately 4000 of these vehicles had the DRL device installed. The remaining 1400 vehicles are assigned to non-maintenance leases and as such did not have the DRL devices installed. This study is conducted on the 4000 vehicles that received the DRL device.

formulation of policy and regulations as well as playing a role in the cost/effectiveness evaluation of possible alternative countermeasure programs.

For example, such information could be used to evaluate the cost/effectiveness of installing the DRL's on the CVA fleet, or the cost/effectiveness of the "Lights On For Life" campaign conducted by the Province. Further, if it can be demonstrated that driving with headlights on during daylight hours is particularly effective, it may be cost/effective for insurance companies to install DRL devices on all vehicles free of charge or it may be desirable to promote DRL devices as standard equipment on all new vehicles.

In summary, driving with headlights on during daylight operations (using DRL devices) may be a cost/effective way to reduce the number and severity of motor vehicle accidents. There is, however, a need to quantify the potential benefits of such in the Saskatchewan setting. With this in mind, the Saskatchewan Government Insurance Corporation, Traffic Safety Service Branch requested proposals from organizations interested in undertaking the study design and subsequent analysis components of the required work. The firm of Clayton, Sparks & Associates Ltd. in association with Decision Focus Incorporated was subsequently commissioned to undertake the required study design and analysis. This document reports the results of this project.

1.2 STUDY OBJECTIVES

The overall objective was to evaluate the effectiveness of the use of daytime running lights on accident rates, accident severity and value of accident claims in the fleet of vehicles owned by the Central Vehicle Agency of the Department of Supply and Services, Government of Saskatchewan and operated by employees of Government Departments and Crown Corporations.

1.3 STUDY SCOPE

The tasks undertaken in this project included the preparation of the study design (i.e. the identification and definition of the methods to be used to evaluate the effectiveness of the use of daytime running lights within the CVA fleet) and the actual performance of the analysis as described in the study design.

The study was to be presented in a report format and was to include:

- a background statement on the concept of DRL use including a literature review on other studies conducted,
- a profile of the accident experience of the CVA fleet over a period of 8 years, and

- a statistical analysis on the impact of using DRL's on accident rates, accident severity and total accident cost.

The background statement was to generally describe the concept of running with headlights on during daylight hours, review and summarize the current literature, and where possible, identify and describe the experience of others related to DRL use.

The profile of the CVA fleet accident experience was to include details related to the number, the cost and severity of accidents for the past 8 years. It was also to identify and quantify the accidents that might be expected to be impacted by the use of DRL's.

The statistical analysis was to determine the impact of DRL's on the CVA fleet accident experience. This impact was quantified as to the statistical significance of the difference in the accident rates before and after the DRL devices were installed. The appropriate statistical testing procedures are identified and justified in this report.

The data used in this study was obtained from the Traffic Accident Information System (TAIS) database. The database is maintained by Saskatchewan Highways and Transportation and contains detailed information about accidents as reported to the local police departments.

2.0 BACKGROUND STATEMENT

2.1 CONCEPT OF DAYTIME RUNNING LIGHT USE

The use of daytime running light's as a possible means of reducing the potential for accidents has been around for many years. In the early 1960's, Greyhound Bus Lines conducted a study in which it ran all of its' buses with lights on for a period of one year. The study found that overall, there was a 12% reduction in accidents, with a 24% reduction observed in Canada (1). Since this time, many other studies have been conducted investigating the effect of daytime headlight use.

The concept of DRL use originated with the problem of reducing accident rates and severity. One of the main reasons that accidents occur is because of the failure of a driver to notice another vehicle. As a possible means to increase vehicle visibility and thus increase driver awareness, the idea of daytime headlight usage was born. The use of DRL's increases the visibility of a vehicle which may in turn reduce the potential for accidents, more particularly, the potential for daytime multiple-vehicle/pedestrian/cyclist accidents.

Headlight use may be especially important during dusk/dawn hours, or during periods of inclement weather when light conditions are less than ideal. Increased visibility of a vehicle translates directly into increased driver awareness, increased time for reaction, and thus increased safety.

DRL use has been studied from many different perspectives. Attwood has conducted many studies and experiments investigating among other things, detection distances of cars with and without headlights on (2). Transport Canada has released reports on the impact of DRL's on fuel consumption and cost of operation (3). Of particular relevance to this project are those studies that deal with actual vehicular accident experience before and after daytime headlight use was implemented. The majority of these studies have been conducted in Canada, the U.S.A., and Scandinavian countries.

A detailed review of three of these studies is presented below. A summary table of each study and the results is also given, followed by a discussion on the important issues as identified in the literature.

2.2 DETAILED REVIEW OF ACTUAL FLEET STUDIES

2.2.1 EFFECTS ON ACCIDENTS OF COMPULSORY USE OF RUNNING LIGHTS DURING DAYLIGHT IN SWEDEN (4)

On October 1st, 1977, a law came into effect that made daytime headlight usage mandatory for all cars and motorcycles in Sweden, regardless of time or location. A study was subsequently conducted to investigate accident rates from October 1975 to September 1979, two years before and two years after the law was implemented.

Data for the study was based on police-reported personal injury accidents. Weather conditions, time of day, light conditions, number of vehicles involved, accident configuration and accident location were all used in the analysis. The methodology used was similar to a previous study on DRL related accidents in Finland (5). (This study is reviewed in the next section.) Accidents were divided into categories of single versus multiple-vehicle and daylight versus darkness. The basic assumption of the study was that only multiple-vehicle daylight accidents would be affected by the use of DRL's.

In an attempt to control the effect of unknown factors, the quotient was established, the quotient being equal to:

$$\Delta = \frac{\dfrac{\text{\# of multiple-vehicle accidents in daylight}}{\text{\# of multiple-vehicle accidents in darkness}}}{\dfrac{\text{\# of single-vehicle accidents in daylight}}{\text{\# of single-vehicle accidents in darkness}}}$$

By the use of this quotient, factors that influence both single and multiple-vehicle accidents, and those that influence both daylight and darkness accidents are eliminated. The result is that changes in Δ reflect selective changes that will affect only one of the four types of accidents (i.e. multiple-vehicle daylight accidents). If the assumption is made that the DRL law is the only selective change that has occurred over the four study years, then the Δ quotient will directly reflect the effect of the DRL Law. While this assumption would greatly simplify matters, it is not necessarily true, therefore a more detailed mathematical model for the statistical analysis (a multiplicative Poisson model) was developed. From the multiplicative Poisson model, the estimated selective change was found to be an 11% decrease in all multiple-vehicle accidents during daylight hours. (This decrease is not significant at the 5% significance level.) Multiple-vehicle daylight accidents were further subdivided according to weather, where no obvious dependence was found, and into accident types, where reductions of 2-21% were found. None of the observed reductions were found to be significant at the 5% level.

2.2.2 THE EFFECT OF RECOMMENDED AND COMPULSORY USE OF VEHICLE LIGHTING ON ROAD ACCIDENTS IN FINLAND (5)

In November 1972, Finland passed a law that made the use of daytime running lights compulsory when driving outside urban areas during the winter months of November to March. This law was revised in 1974 to include the period September 1 to April 30 in all suburban areas. A study was conducted to compare accident experience before and after the law came into effect. The purpose of this study was to investigate the effects of DRL's on traffic accidents. The study covered the period 1968 to 1974.

In order to determine the effects of DRL's on accident experience, some simplifying assumptions were made. The first assumption is that DRL's will affect the risk of daylight collisions but not the risk of accidents during darkness. Secondly, DRL's will not affect the risk of single vehicle accidents. The expectation of the study was that multiple-vehicle accidents during daylight hours would be reduced compared to all other accidents, multiple-vehicle accidents being defined as accidents between a vehicle and either another vehicle, pedestrian, bicycle, or animal.

The data used in this study was subdivided into three time periods. The "before" period ran from July 1968 to June 1970 during which time no regulations related to DRL use were in effect. The second time period was from July 1970 to June 1972 during which time DRL use was advised, and the third period was from July 1972 to June 1974 during which time DRL use was compulsory during winter months (i.e. November to March). Data on accident experience during these three time periods was analyzed along with information on road usage, weather, light conditions and road conditions.

The analysis conducted was very similar to the study conducted in Sweden, discussed in the previous section. The accidents were divided into four main groups, these being:

Multiple-Vehicle Accident during Daylight
Multiple-Vehicle Accident during Darkness
Single Vehicle Accident during Daylight
Single Vehicle Accident during Darkness

These four accident types were analyzed for the summer period and the winter period.

Various types of statistical models for the variance analysis were tested but could not be used to explain the possible DRL effect. This was due to the fact that background factors such as weather conditions, traffic density and daylight each showed a strong correlation to DRL usage, therefore it was impossible to isolate the DRL effect from any other effect. Further, it was necessary to restrict the analysis to include only multiple-vehicle accidents in daylight during the winter months in suburban areas due to a lack of appropriate data for the other periods.

In the end a statistical multiplicative Poisson model was developed that was able to quantify the effect of DRL's on accident rates while eliminating all other background factors such as weather conditions, traffic density and daylight.

An initial analysis showed that from the "before" period to the third time period, there was:

- a 27% decrease in multiple-vehicle daylight accidents
- a 17% increase in multiple-vehicle nighttime accidents
- a 6% increase in single vehicle daylight accidents
- a 12% increase in single vehicle nighttime accidents.

The results of the statistical model indicated that multiple-vehicle accidents in daylight were reduced by 21% from the "before" period. However, because not all of the "other" effects could be eliminated, it was not possible to say how much of this reduction was caused by DRL usage.

2.2.3 FLEET EXPERIENCE WITH DAYTIME RUNNING LIGHTS IN THE USA(6)

In this study, over 2000 cars, vans and light trucks operating in three different vehicle fleets were equipped with an inexpensive relay to turn on the DRL's when the ignition was turned on. The DRL's consisted of the parking lights, with a higher intensity bulb being substituted in the front parking lights. In comparison with similar but unmodified vehicles in the same fleets, the number of DRL related accidents was 7% lower for the DRL equipped vehicles. This difference was not statistically significant.

A DRL-relevant accident was defined as "any multiple-vehicle collision that occurred during daylight including dusk/dawn hours". All types of accident configurations were included regardless of fault, except when the study vehicle rear ended another stopped vehicle and when one car was parked. Other accidents, including all nighttime accidents and single vehicle accidents were used as part of the control group. The key measure of effectiveness was thus the difference in the ratio of DRL-related accidents to total multi-vehicle accidents for modified vehicles versus the control vehicles. Accidents were further subdivided by configuration into opposing direction, angle, same direction and other. The effect DRL's have in adverse weather was also studied.

The results of the study showed that the proportion of DRL-relevant accidents was 7% lower than for the control group. Although this drop was not statistically significant, it was concluded that, when taken with all the other evidence, DRL's have accident reduction potential. Detailed analysis also showed that DRL's appear to be more effective under adverse weather conditions, probably due to reduced ambient light conditions.

2.2.4 SUMMARY TABLE OF FLEET STUDIES

TABLE 1

SUMMARY OF STUDIES AND RESULTS

	STUDY DETAILS	RESULTS
1. Greyhound Bus Lines (1)	Ran all buses with head lights on for one year in early '60s.	Overall,12% drop in accidents. In Canada, 24% reduction.

2. AT & T (1)	Ran entire fleet of vehicle with headlights on in 1973	Overall 32% drop in accidents during first 6 months as compared to the same period in 1972
3. Survey of U.S. Companies (1)	Surveyed 181 U.S. companies that operate fleets with lights on	Decreases in accidents up to 38% reported
4. Four States with DRL Laws for Motorcycles (1)	Compared multi-vehicle daytime collisions of 4 States with DRL Laws against 4 States without DRL laws	40% reduction in accidents in 4 States with DRL laws. 3% drop in no law states Not all 40% due to DRL Law.
5. Checker Cab vs Yellow Cab (1)	Year long period where Checker Cab Co. used DRL and Yellow Cab Co. used no lights	Checker Cab Co. had 7.2% overall drop in accident rates.
6. North Carolina "Lights On" Legislation (1)	Compared data three years before to three years after legislation	5% reduction in proportion of daytime multi-vehicle crashes
7. Canadian Motorcycle Fatality & Casualty Rates (1)	Compared fatality and injury rates from 1960 - 1978	Introduction of legislation in 1975 had a marked effect on both rates. 1976 was 11 year low for deaths and 16 year low for injuries.

8. Norwegian Crash Data (1)	Statistical Study Examined all vehicle crash data from 1969 - 1973	Single vehicle accident ratio (dark : daytime) was 3x higher than same ratio for multiple-vehicle accidents. Concluded difference was due to more vehicle lights during dark periods.
9. New York Port Authority, 1965 (1)	1965 - Modified 38 vehicles to operate with DRL automatically	After one year there was a statistically significant reduction in accident rates.
10. New York Port Authority, 1967 (1)	1967 - Modified 200 vehicles to operate with DRL automatically. Compared modified vehicles to group of unmodified	18% fewer collisions per million vehicle miles. Crash severity per million vehicle miles was down 66% for modified group.
11. Finland (4)	Six year data collection 1968-74. Introduced legislation 1972	27% drop in day time multi-vehicle accident rate while all other accident rates rose.
12. Transport Canada with Department of National Defense (1)	175 military vehicles modified to operate with DRL's and paired with 175 that weren't. 21 month data collection from March 1975	Fewer daytime multi-vehicle collisions among modified group. Not statistically significant due to low number of accidents

13. Sweden (5)	Legislation on mandatory headlight use introduced Oct/77. Compared accident rates 2 years before and 2 years after legislation	6-13% reduction in multi-vehicle daytime accidents.
14. Fleet Experience in US (6)	2000 vehicles in 3 different vehicle fleets modified to operate with DRL in '83/84	Overall, DRL relevant crashes down 7% in DRL equipped vehicles.

2.3 IMPORTANT ISSUES RELATED TO DRL STUDY

From the literature review, several important issues are identified that will need to be addressed in this study. First, it is important to have a good database from which to draw information. When isolating specific accidents, accurate and detailed information is required. For example, isolating daytime collisions could be extremely difficult if "Time of Day" is missing on the accident form.

It is also important to know what to look for in the accident analysis. A DRL-related accident is broadly defined as a multiple-vehicle accident that occurs during daylight hours. Multiple-vehicle accidents include accidents involving a vehicle and another vehicle, cyclist or pedestrian, but should not include collisions with parked cars. Daylight hours should include dusk/dawn hours and all hours in between. This definition is complicated even further when dealing with the issue of who is at fault. That is, an accident where the DRL-equipped vehicle is the striking vehicle (ie. at fault), will not be affected by headlight usage, yet would still fit into the definition given above.

Another issue is that of defining the control group, or to what standard do we compare accident experience. As noted from the literature, there are two different ways to deal with this problem. The first is to obtain data on a separate group of vehicles that have similar conditions of usage. The number of DRL-relevant accidents in each group can then be compared to see if daylight headlight usage has an effect on accident rates. The second way is to define those accidents that (theoretically) are not affected by DRL's as the control group. These accidents would include accidents occurring in the dark and all single vehicle accidents since the use of DRL's should not have any effect on these types of accidents. The trends observed in these

two accident groups (ie. the DRL-related accidents and the non-DRL affected accidents) can then be compared to determine the effect of DRL's on accident experience.

Along with the installation of DRL devices, any other changes which may affect accident rates should be considered. These would typically include changes in traffic density, annual vehicle mileage, accident reporting procedures and weather conditions, all of which may bias the results obtained. For example, if annual vehicle mileage is much higher during a particular year, the number of accidents could be expected to be higher, regardless of DRL use. A possible solution to this particular problem would be to compare accident rates, (ie. accidents per million vehicle miles).

3.0 PROFILE OF CVA FLEET ACCIDENT EXPERIENCE

3.1 INTRODUCTION

The profile of CVA accident experience is presented in a number of steps or components. These components are identified in Figure 1. The profile begins by presenting details related to the CVA fleet exposure. The CVA accident experience for total number, total cost, and the number of accidents by severity for all CVA accidents is then presented. These numbers are then broken down step by step as illustrated in Figure 1 until the number, cost, severity and configuration of DRL-related accidents are obtained.

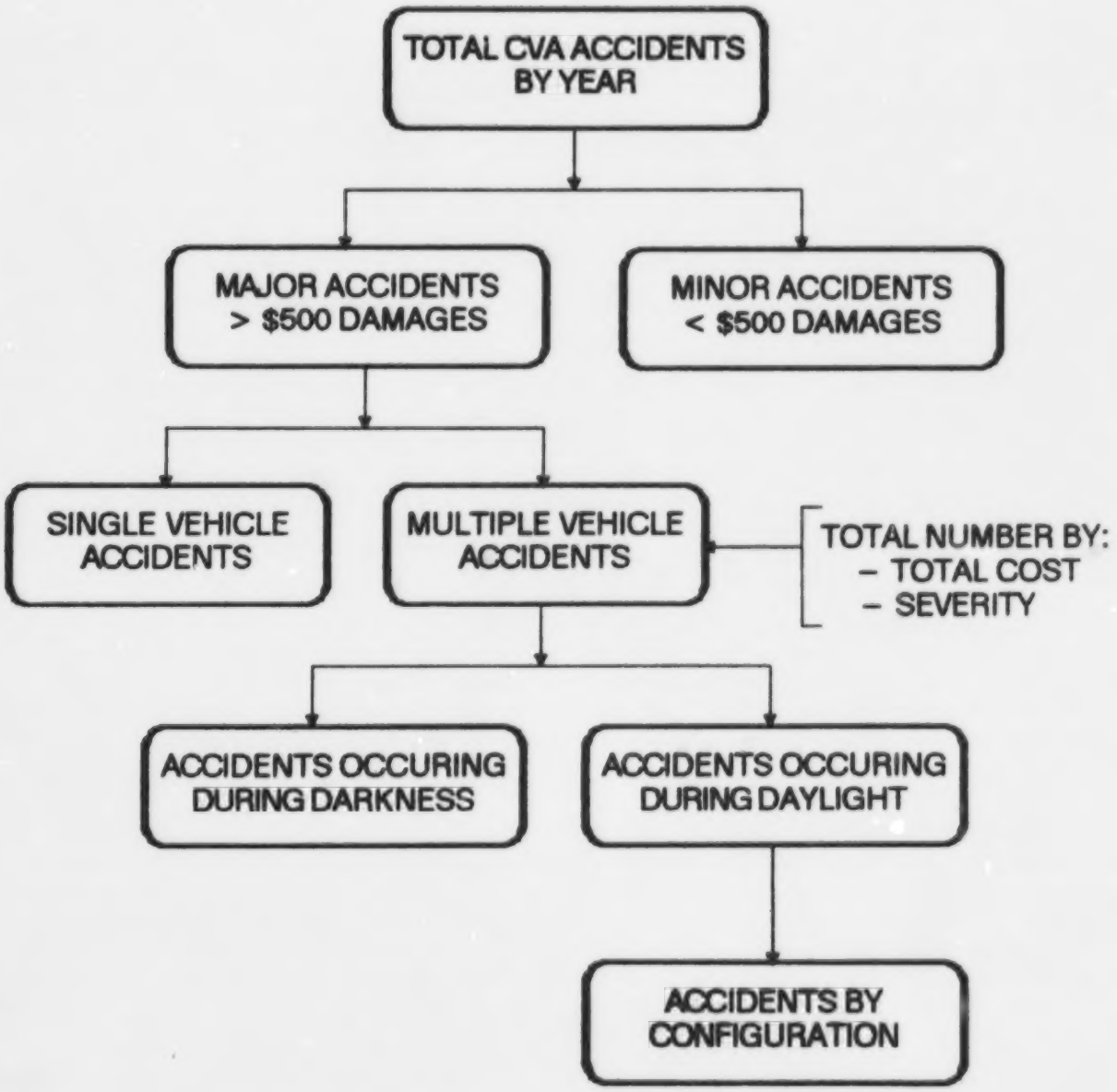
As will be illustrated later, a review of this data indicates that a change in the definition of a reportable accident at the end of 1983 from one involving more than $200 in damages to one involving more than $500 in damages has had a dramatic impact on the total number of accidents reported each year prior to 1983 relative to those years following 1983. This change in definition has implications on the statistical analysis therefore the impact of this change was removed from the analysis by removing all accidents with property damage of $500 or less from the data considered (i.e. all fender-bender type accidents were removed). In the context of this study, this is reasonable because this removes the effect of the change in the definition of an accident.

The second component of the profile presents the details of major accidents (i.e. accidents with property damage greater than $500) in terms of the total number and the total cost of accidents by year, as well as the number of accidents by severity by year.

In terms of this study, multiple-vehicle accidents are of primary concern because it is upon this component of the total accidents that the use of DRL's would be expected to have an impact. That

FIGURE 1

COMPONENTS OF THE CVA FLEET ACCIDENT PROFILE



is, DRL's are unlikely to reduce the number or severity of single vehicle accidents. Therefore the third component of the profile details the number and the cost of multiple-vehicle accidents by year, as well as provides the details related to the number of multiple-vehicle accidents by severity by year.

As noted above, multiple-vehicle accidents are of primary concern in terms of DRL's. This component of the total accidents can be further segmented in terms of time of the accident (i.e. daytime versus darkness). Obviously the component involving multiple-vehicle accidents occurring during daylight hours are of particular interest to this study. The multiple-vehicle accidents occurring during darkness hours are not relevant to this study (beyond providing a control group) since headlights would have been used during the darkness hours even before DRL devices were installed. Therefore, the fourth component of the profile provides details related to the number and the total cost of multiple-vehicle daytime accidents by year as well as the number of daylight accidents by severity by year.

In terms of evaluating the impact of DRL's, it would be highly desirable if the impact of DRL's could be identified in terms of the type (i.e. configuration) of accidents impacted. Therefore the fifth component of the profile presents the details related to the number and the cost of CVA multiple-vehicle, daytime accidents with damages exceeding $500, by configuration of accident, by year as well as the number of accidents by configuration, by severity by year.

In short, the profile of CVA accident experience presents details of various components of the total CVA accident experience and focuses upon the accidents of particular interest (i.e. those that might be expected to be impacted by the use of DRL's), namely major (> $500 damages), multiple-vehicle, daytime accidents. The remainder of the CVA accidents (ie. single vehicle and darkness accidents) are summarized where applicable and are subsequently used for comparison purposes in the statistical analysis.

It should be noted that the data presented for the years 1980 to 1985 inclusive is based on a January to December period. The 1986 and 1987 data is base on a June to May period. The reason for this was to provide a better segregation of pre-DRL installation data with post-DRL installation data. That is, the automatic DRL devices were installed from May to September, 1986. By moving the 1986 and 1987 cycle up (ie. June to May) the 1986 data would include (almost) exclusively post-DRL data. Thus, the DRL effect (if any) should be better reflected in the data.

3.2 EXPOSURE OF THE CVA FLEET

As identified in the literature review, it is important that vehicle exposure be considered in the analysis. Table 2 presents the details related to the average exposure of CVA vehicles. It is assumed for this study that the total number of vehicles in the fleet and the average vehicular exposure remain constant throughout the study period. This is a reasonable assumption, given the data presented in Table 2.

TABLE 2

AVERAGE ANNUAL DISTANCE PER VEHICLE IN THE CVA FLEET

Year	# of Vehicles in CVA Fleet as of March 31	Average Annual Distance per Vehicle (km)	Total Vehicle Exposure (veh.km x 10e6)
81/82	5288	25,200	133
82/83	5469	24,384	133
83/84	5440	24,828	135
84/85	5450	24,216	132
85/86	5147	25,805	133
86/87	5165	26,110	135
87/88	4977	25,752	128

NOTE: The data presented is "as at March 31" of the given year. The actual number of vehicles in the fleet at any one time may be more or less than that given, due to any number of variables including the sale of obsolete vehicles, the arrival of new vehicles, etc.. The CVA fleet managers were unable to identify any major changes that would have altered fleet exposure (ie. the lower number of vehicles in 87/88) and hence the lower exposure could not be explained and was viewed as a normal fluctuation. Therefore, it is assumed that the exposure remained constant over the study period.

3.3 PROFILE OF TOTAL ACCIDENTS

Table 3 summarizes and Figure 2 illustrates the total number of reportable CVA accidents by year for 1980 to 1987. From Table 3 and Figure 2 it is noted that the number of reported accidents decreased dramatically after 1983 (ie. 1984 to 1987). As noted previously, this decrease in reportable accidents is in part attributable to a change in the definition of a reportable accident on January 1, 1984, from one involving more than $200 in damages to one involving more than $500 in damages.

Table 4 summarizes and Figure 3 illustrates the total cost of CVA

TABLE 3

TOTAL NUMBER OF CVA ACCIDENTS BY YEAR

YEAR	NUMBER OF ACCIDENTS
1980	796
1981	592
1982	643
1983	533
1984	411
1985	413
1986	416
1987	350
TOTAL	4154

1.) 16 ACCIDENTS NOT INCLUDED DUE TO MISSING DATA.
2.) TOTAL CASES = 4170
3.) THE DOLLAR VALUE OF A REPORTABLE ACCIDENT CHANGED FROM $200 TO $500 ON JANUARY 1st, 1984.
4.) 1986 AND 1987 DATA ARE FROM JUNE 1st OF THE YEAR INDICATED UNTIL MAY 31st OF THE FOLLOWING YEAR. 1980 TO 1985 DATA ARE FOR JANUARY TO DECEMBER.

FIGURE 2

TOTAL NUMBER OF CVA ACCIDENTS

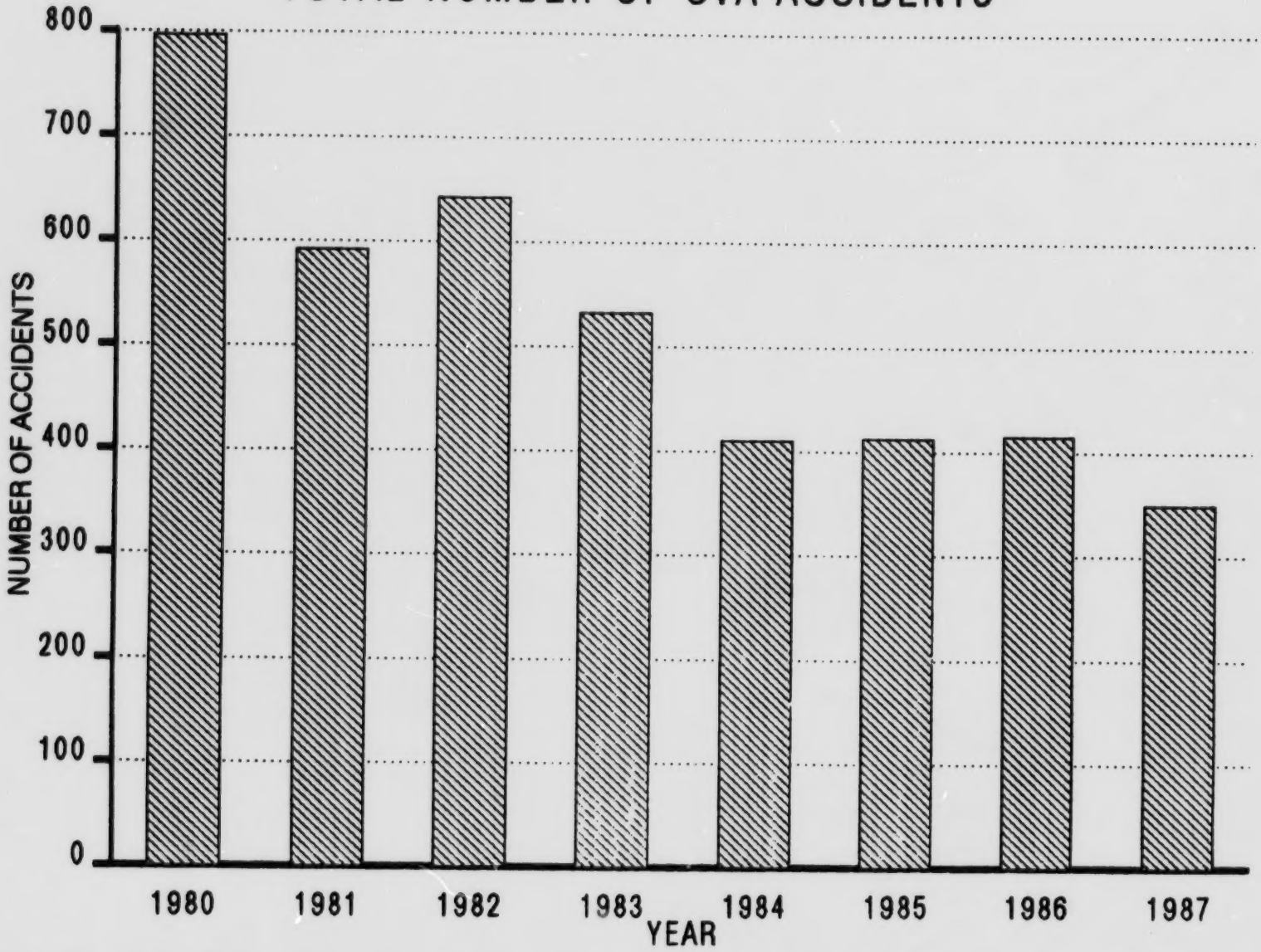


TABLE 4

TOTAL COST OF CVA ACCIDENTS BY YEAR

YEAR	NUMBER OF CASES *	TOTAL COST ($) **	AVERAGE COST ($/accident)
1980	796	838,816	1,053.79
1981	592	1,047,662	1,769.70
1982	643	1,149,834	1,788.23
1983	533	1,162,207	2,180.50
1984	411	953,808	2,320.70
1985	413	1,279,778	3,098.74
1986	416	1,283,351	3,084.98
1987	350	1,110,681	3,173.37
TOTAL	4154	8,826,137	

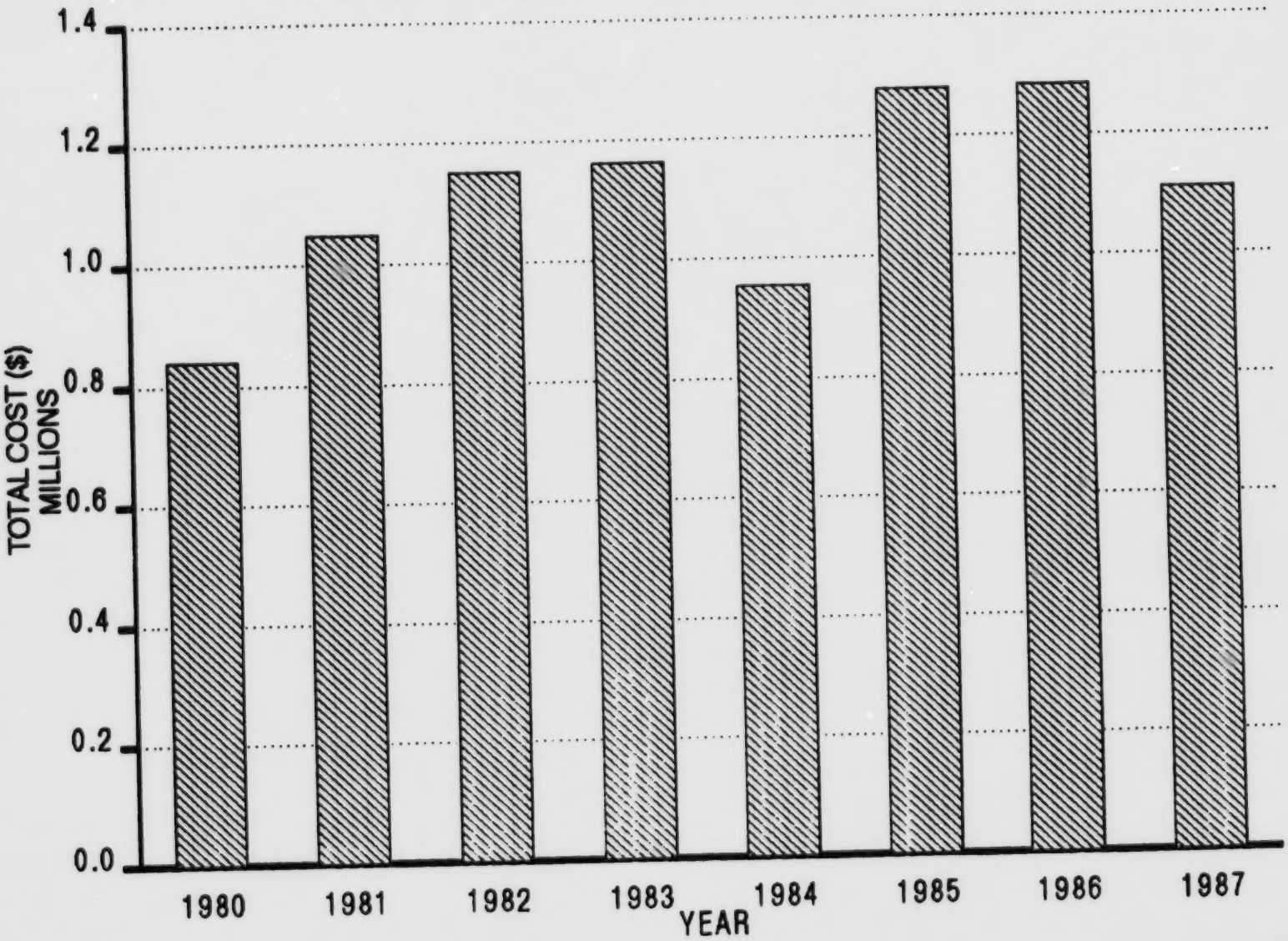
NOTE: 1.) 16 ACCIDENTS ARE NOT INCLUDED MISSING DATA.
2.) TOTAL CASES = 4170
3.) THE DOLLAR VALUE OF A REPORTABLE ACCIDENT CHANGED FROM $200 TO $500 ON JANUARY 1st, 1984.
4.) 1986 AND 1987 DATA ARE FROM JUNE 1st OF THE YEAR INDICATED UNTIL MAY 31st OF THE FOLLOWING YEAR. 1980 TO 1985 DATA ARE FOR JANUARY TO DECEMBER.

* NOTE THAT THE NUMBER OF CASES (ie. ACCIDENTS) USED HERE MAY BE SOMEWHAT DIFFERENT THAN THE TOTAL PRINTED IN TABLE 1. THIS IS BECAUSE NOT ALL DATA IS AVAILABLE FOR ALL ACCIDENTS FROM THE DATA BASE. ANY ACCIDENT WITH INCOMPLETE DATA RELATIVE TO THE PARAMETERS CONSIDERED IS ELIMINATED FROM THE SUMMARY.

** ALL COSTS PRESENTED IN THIS REPORT ARE POLICE ESTIMATES RATHER THAN ACTUAL COSTS OF REPAIR

FIGURE 3

TOTAL COST OF CVA ACCIDENTS



accidents by year for 1980 to 1987 [2]. It is noted that the total cost of CVA accidents has increased from $0.8 million in 1980 to $1.3 million in 1985 and slightly decreased to $1.1 million in 1987. It is important to note that this general increasing trend in total costs occurred at the same time as the total number of reported accidents decreased substantially (ie. from 796 in 1980 to 413 in 1985 to 350 in 1987). That is, the average estimated cost of a CVA accident in 1980 was $1053, in 1985 it was $3098, and in 1987 it was $3,173. This increase in total costs reflects a substantial increase in costs of repairs, etc. over the 1980 to 1987 period.

Table 5 and Figure 4 illustrate the number of accidents by severity, by year. As noted, most accidents in terms of total numbers involve property damage (ie. 81 to 90%) with fewer involving personal injury (8 to 18%) and still fewer involving fatalities (0 to 1%). It is also noted from Figure 4 that consistent with previous discussion, the number of property damage accidents has decreased, in part because of the change in definition of a reportable accident, while the number of personal injury accidents and fatalities has remained fairly stable over time (except for the 1987 data). This is attributable to the fact that personal injury and fatality accidents are not likely to occur except in high property damage accidents and would therefore not be expected to be affected by a change in the definition of a reportable accident.

3.4 PROFILE OF ACCIDENTS WITH DAMAGES OF MORE THAN $500

It is desirable for analysis purposes to remove the implication of the change in the definition of a reportable accident. This was done by removing all accidents with damages of $500 or less from the data.

Table 6 summarizes and Figure 5 illustrates the total number of CVA accidents with damages exceeding $500 by year. As can be noted from Figure 5, the number of major accidents (ie. >$500 in damages) was relatively stable from 1980 to 1986 with a slight reduction observed in 1987. The number of accidents range from a low of 332 in 1987 to a high of 413 in 1983, averaging 372 accidents per year.

Table 7 summarizes and Figure 6 illustrates the total estimated cost of CVA accidents by year for those accidents involving damages of more than $500. The increasing cost of major accidents (i.e. $1830 per accident in 1980 to $3435 in 1985) reflects as would be expected, the increasing costs of repairs. From 1985 to 1987 the average cost has remained relatively

---

2 These costs are estimates by police entered on the accident report as opposed to actual costs of claims.

TABLE 5

TOTAL NUMBER OF CVA ACCIDENTS BY SEVERITY

YEAR	ACCIDENT SEVERITY						TOTAL
	PROPERTY DAMAGE		PERSONAL INJURY		FATALITY		
	NUMBER	% OF YEAR	NUMBER	% OF YEAR	NUMBER	% OF YEAR	
1980	710	90.7	70	8.9	3	0.4	783
1981	516	88.2	67	11.5	2	0.3	585
1982	559	87.8	71	11.1	7	1.1	637
1983	455	86.0	71	13.4	3	0.6	529
1984	335	83.1	68	16.9	0	0.0	403
1985	350	84.7	60	14.5	3	0.7	413
1986	341	82.0	74	17.8	1	0.2	416
1987	303	86.6	44	12.6	3	0.9	350
TOTAL	3569		525		22		4116

NOTE: 1.) 54 ACCIDENTS ARE NOT INCLUDED DUE TO MISSING DATA.
2.) TOTAL CASES = 4170
3.) THE DOLLAR VALUE OF A REPORTABLE ACCIDENTS CHANGED FROM $200 TO $500 ON JANUARY 1st, 1984.
4.) 1986 AND 1987 DATA ARE FROM JUNE 1st OF THE INDICATED YEAR UNTIL MAY 31st OF THE FOLLOWING YEAR. 1980 TO 1985 DATA ARE FOR JANUARY TO DECEMBER.

FIGURE 4

ACCIDENT SEVERITY

ALL CVA ACCIDENTS

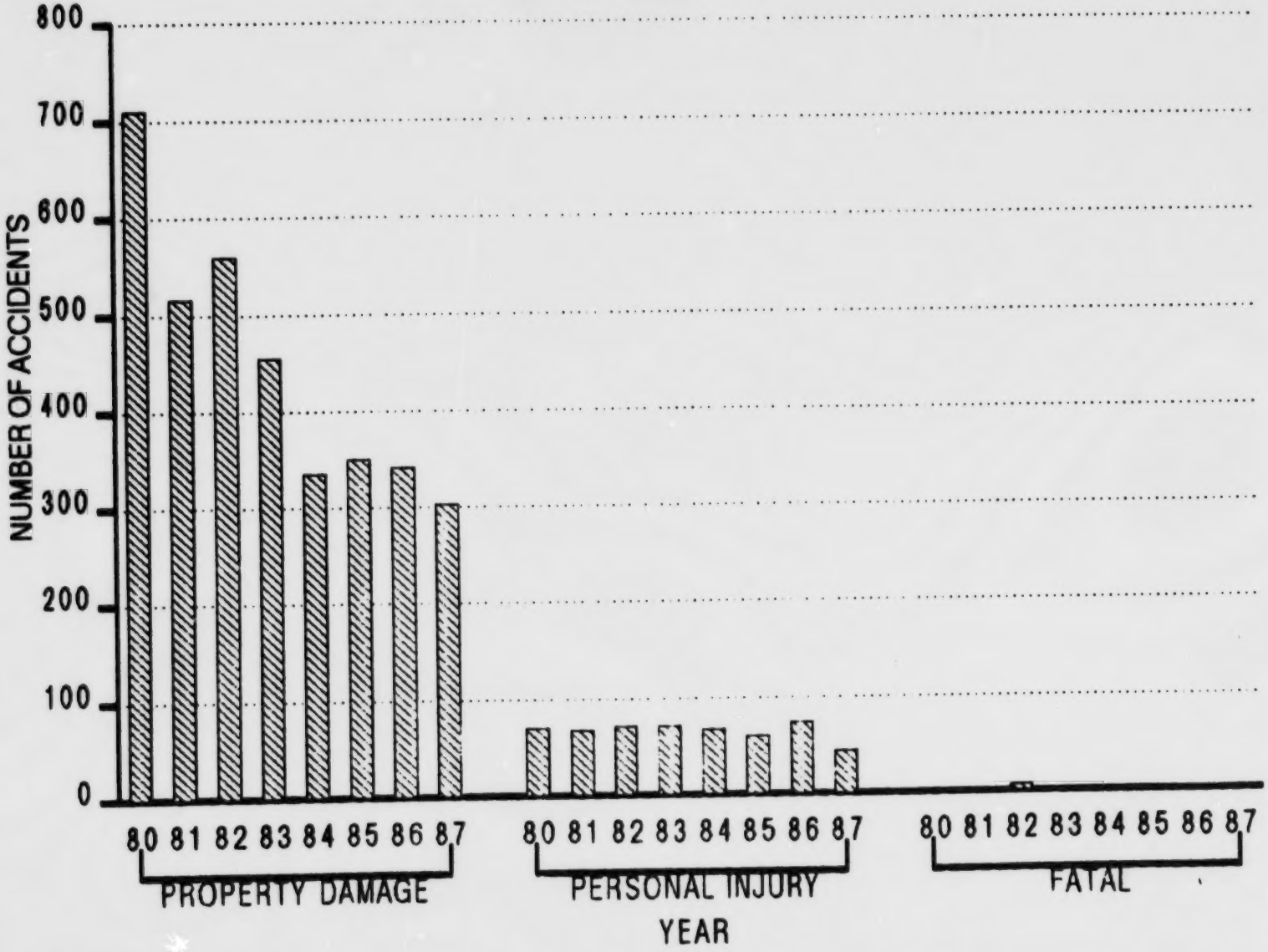


TABLE 6

TOTAL NUMBER OF CVA ACCIDENTS
EXCEEDING $500 IN DAMAGES BY YEAR

YEAR	NUMBER OF ACCIDENTS		
	TOTAL	$500 AND LESS	MORE THAN $500
1980	796	409	387
1981	592	207	385
1982	643	230	413
1983	533	176	357
1984	411	47	364
1985	413	45	368
1986	416	50	366
1987	350	18	332
TOTAL	4154	1182	2972

NOTE: 1.) 16 ACCIDENTS ARE NOT INCLUDED DUE TO MISSING DATA.
2.) TOTAL CASES = 4170
3.) THE DOLLAR VALUE OF A REPORTABLE ACCIDENT CHANGED FROM $200 TO $500 ON JANUARY 1st, 1984.
4.) 1986 AND 1987 DATA ARE FROM JUNE 1st OF THE YEAR INDICATED UNTIL MAY 31st OF THE FOLLOWING YEAR. 1980 TO 1985 DATA ARE FOR JANUARY TO DECEMBER.

FIGURE 5

TOTAL NUMBER OF CVA ACCIDENTS

EXCEEDING $500 IN DAMAGES

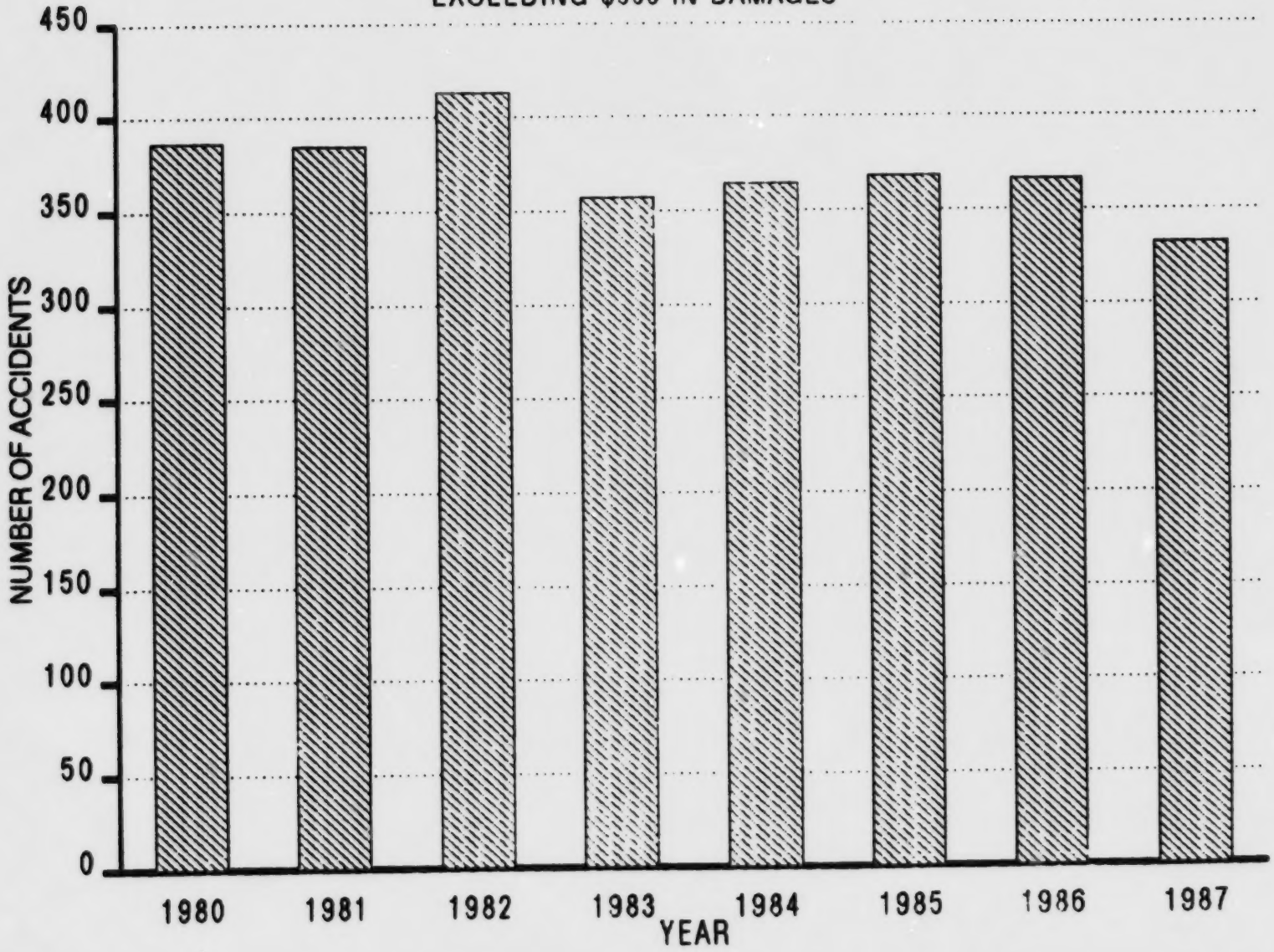


TABLE 7

TOTAL COST OF CVA ACCIDENTS BY YEAR
FOR ACCIDENTS WITH DAMAGES GREATER THAN $500

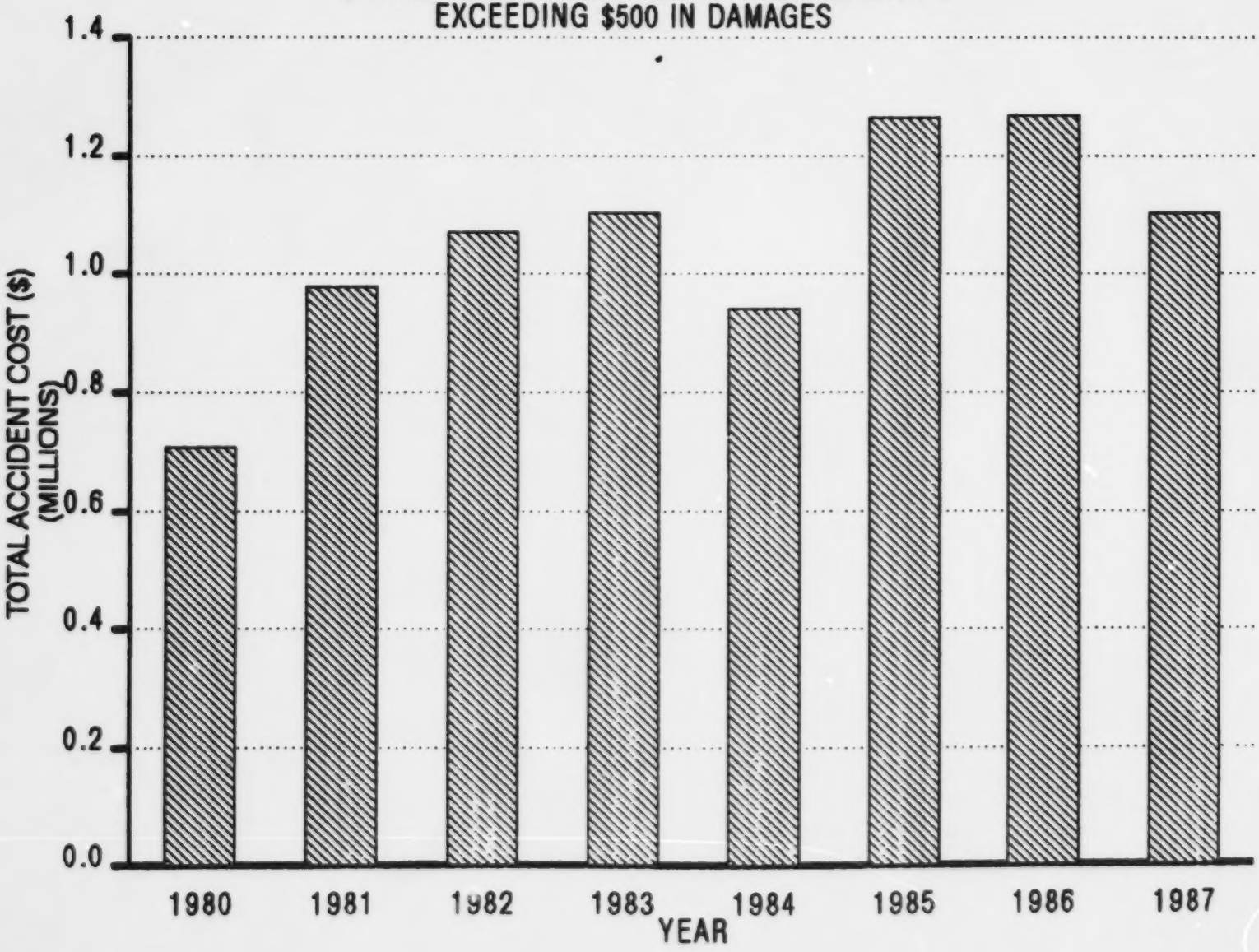
YEAR	NUMBER OF ACCIDENTS	TOTAL COST ($)	AVERAGE COST ($/VEH.)
1980	387	708,208	1,830.0
1981	385	978,699	2,542.1
1982	413	1,071,388	2,594.2
1983	357	1,103,632	3,091.4
1984	364	940,078	2,582.6
1985	368	1,264,368	3,435.8
1986	366	1,267,457	3,463.0
1987	332	1,103,681	3,324.3
TOTAL	2972	8,437,511	

NOTE1.) 4 ACCIDENTS ARE NOT INCLUDED DUE TO MISSING DATA.
2.) TOTAL CASES = 2976
3.) 1986 AND 1987 DATA ARE FROM JUNE 1st OF THE YEAR INDICATED UNTIL MAY 31st OF THE FOLLOWING YEAR.

FIGURE 6

TOTAL COST OF CVA ACCIDENTS

EXCEEDING $500 IN DAMAGES



stable.

Table 8 and Figure 7 illustrate the number of accidents exceeding $500 in damages by severity, by year. There has been on average, 315 property damage, 53 personal injury and 2.5 fatal CVA accidents per year involving costs greater than $500. As noted from Figure 7, these major accidents have remained relatively stable over time with a slight downward trend in the 1986 and 1987 data.

3.5 PROFILE OF SINGLE AND MULTIPLE-VEHICLE CVA ACCIDENTS

Our primary interest in this project is directed to determining the impact of daytime running lights on accidents. DRL's would be expected to have an impact upon some multiple-vehicle accidents whereas their use would not be expected to have an impact upon (most) single vehicle accidents. As a result, it is of interest to profile the characteristics of single and multiple-vehicle accidents separately.

Table 9 and Figure 8 illustrate the number of single and multiple-vehicle CVA accidents with damages exceeding $500 by year. About 20% of all CVA accidents involve single vehicles and 80% multiple vehicles. Also, as can be noted from Figure 8, there has been considerable stability over time in the number of single vehicle accidents. The number of multiple-vehicle accidents was relatively stable from 1980 to 1985. A slight decreasing trend is observed in the 1986 and 1987 data.

Table 10 and Figure 9 illustrate the cost of single and multiple-vehicle CVA accidents with damage greater than $500 by year. As noted from Figure 9, there has been considerable year to year variability for single vehicle accidents and a generally increasing trend in costs for the multiple-vehicle accidents.

Table 11 and Figure 10 illustrate the number of CVA accidents involving damages exceeding $500 by severity for single and multiple vehicle accidents by year. Multiple-vehicle accidents clearly dominate in total numbers in each of the severity categories.

3.6 PROFILE OF MULTIPLE-VEHICLE ACCIDENTS BY LIGHT CONDITIONS

Table 12 and Figure 11 illustrate the number of CVA multiple-vehicle accidents involving damages greater than $500 by time of occurrence (daylight or darkness). As noted, daylight accidents account for approximately 85% of the total number of these types of accidents. Further, there is no observable trend in the number of darkness accidents from 1980 to 1987. The number of daylight accidents has shown a decrease in the most recent years (ie. 1986 and 1987).

TABLE 8

NUMBER OF CVA ACCIDENTS BY YEAR BY ACCIDENT SEVERITY
FOR ACCIDENTS WITH DAMAGES GREATER THAN $500

YEAR	ACCIDENT SEVERITY						TOTAL
	PROPERTY DAMAGE		PERSONAL INJURY		FATALITY		
	NUMBER	% OF YEAR	NUMBER	% OF YEAR	NUMBER	% OF YEAR	
1980	336	87.3	48	12.5	1	0.3	385
1981	326	84.9	56	14.6	2	0.5	384
1982	346	84.0	59	14.3	7	1.7	412
1983	293	82.8	58	16.4	3	0.8	354
1984	307	85.8	51	14.2	0	0.0	358
1985	314	85.3	51	13.9	3	0.8	368
1986	307	83.9	58	15.8	1	0.3	366
1987	290	87.3	39	11.7	3	0.9	332
TOTAL	1922		323		16		2959

NOTE: 1.) 17 ACCIDENTS ARE NOT INCLUDED DUE TO MISSING DATA.
2.) TOTAL CASES = 2976
3.) 1986 AND 1987 DATA ARE FROM JUNE 1st OF THE YEAR INDICATED UNTIL MAY 31st OF THE FOLLOWING YEAR.

FIGURE 7

ACCIDENT SEVERITY

FOR CVA ACCIDENTS EXCEEDING $500 DAMAGE

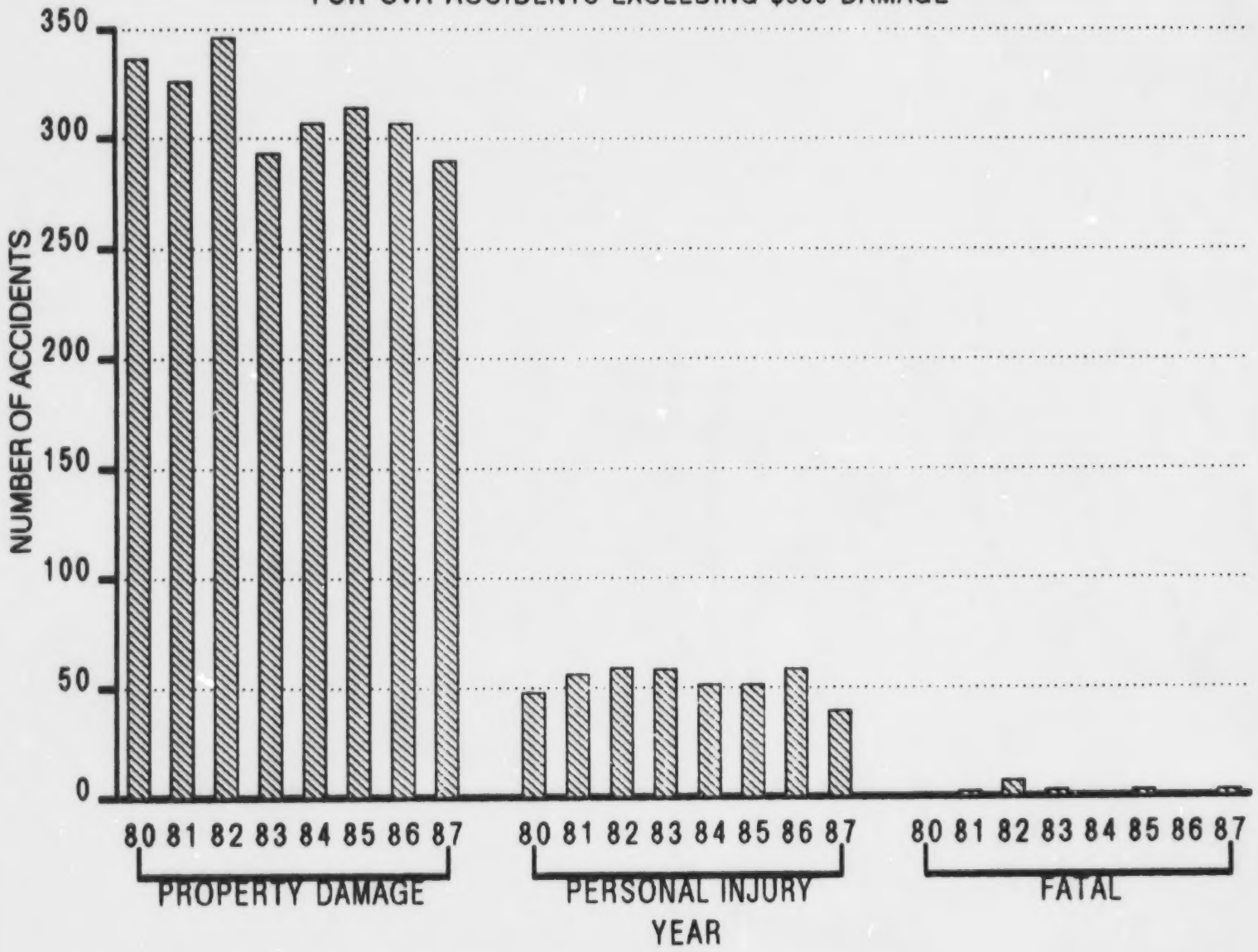


TABLE 9

TOTAL NUMBER OF SINGLE & MULTIPLE VEHICLE CVA ACCIDENTS
BY YEAR FOR ACCIDENTS WITH DAMAGES EXCEEDING $500

YEAR	TOTAL NUMBER	SINGLE VEHICLE	MULTIPLE VEHICLE
1980	385	77	308
1981	384	77	307
1982	412	86	326
1983	354	73	281
1984	358	76	282
1985	368	75	293
1986	366	81	285
1987	332	85	247
TOTAL	2959	630	2329

NOTE: 1.) 17 ACCIDENTS ARE NOT INCLUDED DUE TO MISSING DATA.
2.) TOTAL CASES = 2976
3.) 1986 AND 1987 DATA ARE FROM JUNE 1st OF THE YEAR INDICATED UNTIL MAY 31st OF THE FOLLOWING YEAR.

FIGURE 8

SINGLE AND MULTIPLE VEHICLE ACCIDENTS

FOR CVA ACCIDENTS EXCEEDING $500 DAMAGE

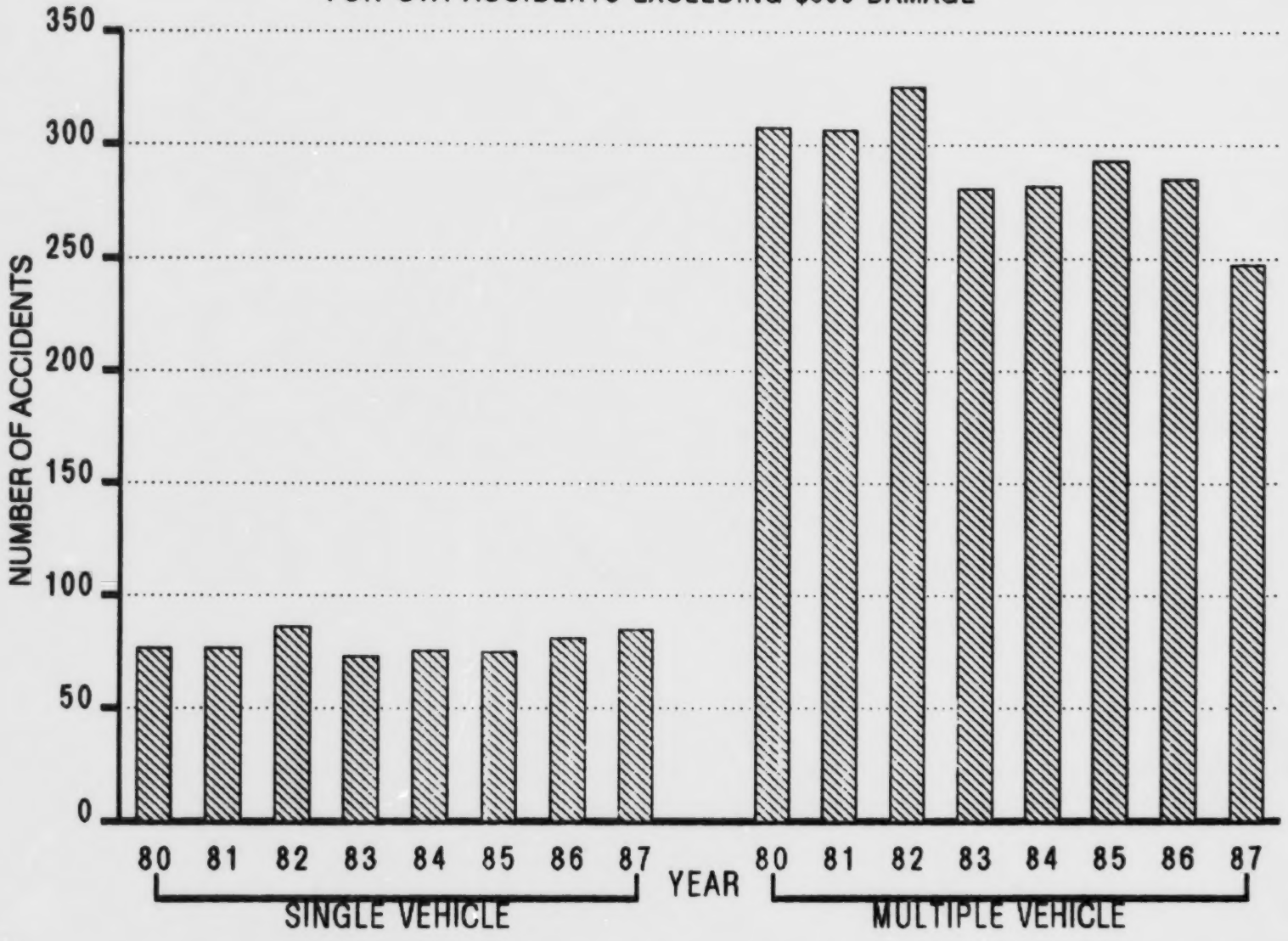


TABLE 10

TOTAL COST OF ACCIDENTS FOR SINGLE AND MULTIPLE VEHICLE ACCIDENTS BY YEAR FOR CVA ACCIDENTS WITH DAMAGES GREATER THAN $500

YEAR	SINGLE VEHICLE			MULTIPLE VEHICLE		
	NO. OF ACCIDENTS	TOTAL COST ($)	AVERAGE COST ($/veh)	NO. OF ACCIDENTS	TOTAL COST ($)	AVERAGE COST ($/veh)
1980	77	188,450	2,447.4	308	518,058	1,682.0
1981	77	178,568	2,319.1	307	799,331	2,603.7
1982	86	237,300	2,759.3	326	833,480	2,556.7
1983	73	216,875	2,970.9	281	883,707	3,144.9
1984	76	179,307	2,359.3	282	747,071	2,649.2
1985	75	338,691	4,515.9	293	925,677	3,159.3
1986	81	287,543	3,549.9	285	979,914	3,438.2
1987	85	251,433	2,958.0	247	852,248	3,450.4
TOTAL	630	1,878,167		2,329	6,539,486	

NOTE: 1.) 17 ACCIDENTS NOT INCLUDED DUE TO MISSING DATA.
2.) TOTAL CASES = 2976
3.) 1986 AND 1987 DATA ARE FROM JUNE 1st OF THE YEAR INDICATED UNTIL MAY 31st OF THE FOLLOWING YEAR.

FIGURE 9

TOTAL COST OF ACCIDENTS

FOR CVA ACCIDENTS EXCEEDING $500 DAMAGE

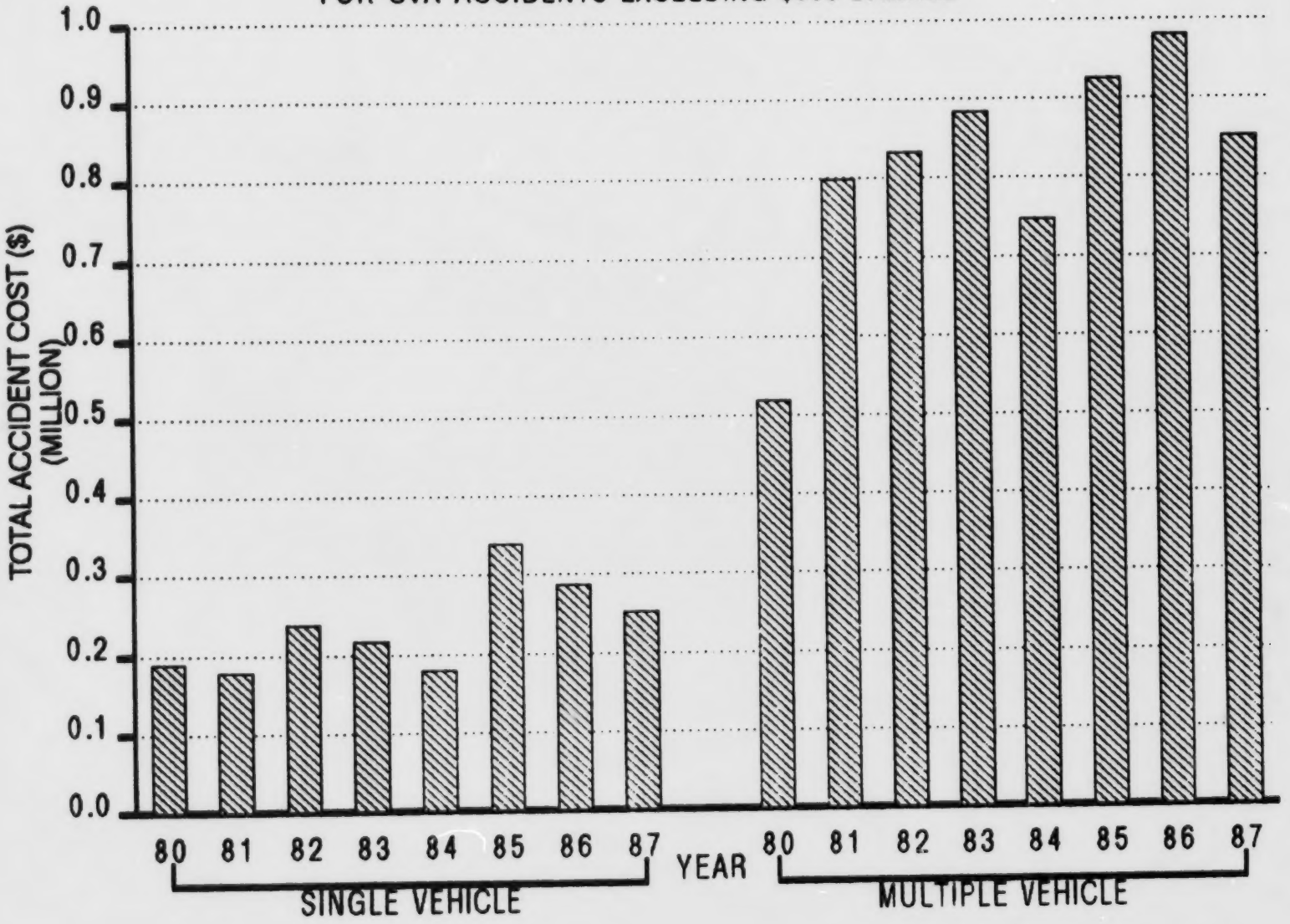


TABLE 11

NUMBER OF SINGLE AND MULTIPLE VEHICLE ACCIDENTS BY YEAR BY ACCIDENT SEVERITY FOR CVA ACCIDENTS WITH DAMAGES GREATER THAN $500

YEAR	PROPERTY DAMAGE		PERSONAL INJURY		FATALITY		TOTAL
	SINGLE VEHICLE	MULTIPLE VEHICLE	SINGLE VEHICLE	MULTIPLE VEHICLE	SINGLE VEHICLE	MULTIPLE VEHICLE	
1980	64	272	12	36	1	0	385
1981	68	258	9	47	0	2	384
1982	70	276	16	43	0	7	412
1983	58	235	15	43	0	3	354
1984	66	241	10	41	0	0	358
1985	67	247	8	43	0	3	368
1986	65	242	15	42	1	0	365
1987	74	216	10	29	1	2	332
TOTAL	532	1,987	95	324	3	17	2,958

NOTE: 1.) 18 ACCIDENTS NO INCLUDED DUE TO MISSING DATA.
2.) TOTAL CASES = 2976
3.) 1986 AND 1987 DATA ARE FROM JUNE 1st OF THE YEAR INDICATED UNTIL MAY 31st OF THE FOLLOWING YEAR.

FIGURE 10

ACCIDENT SEVERITY

FOR CVA ACCIDENTS EXCEEDING $500 DAMAGE

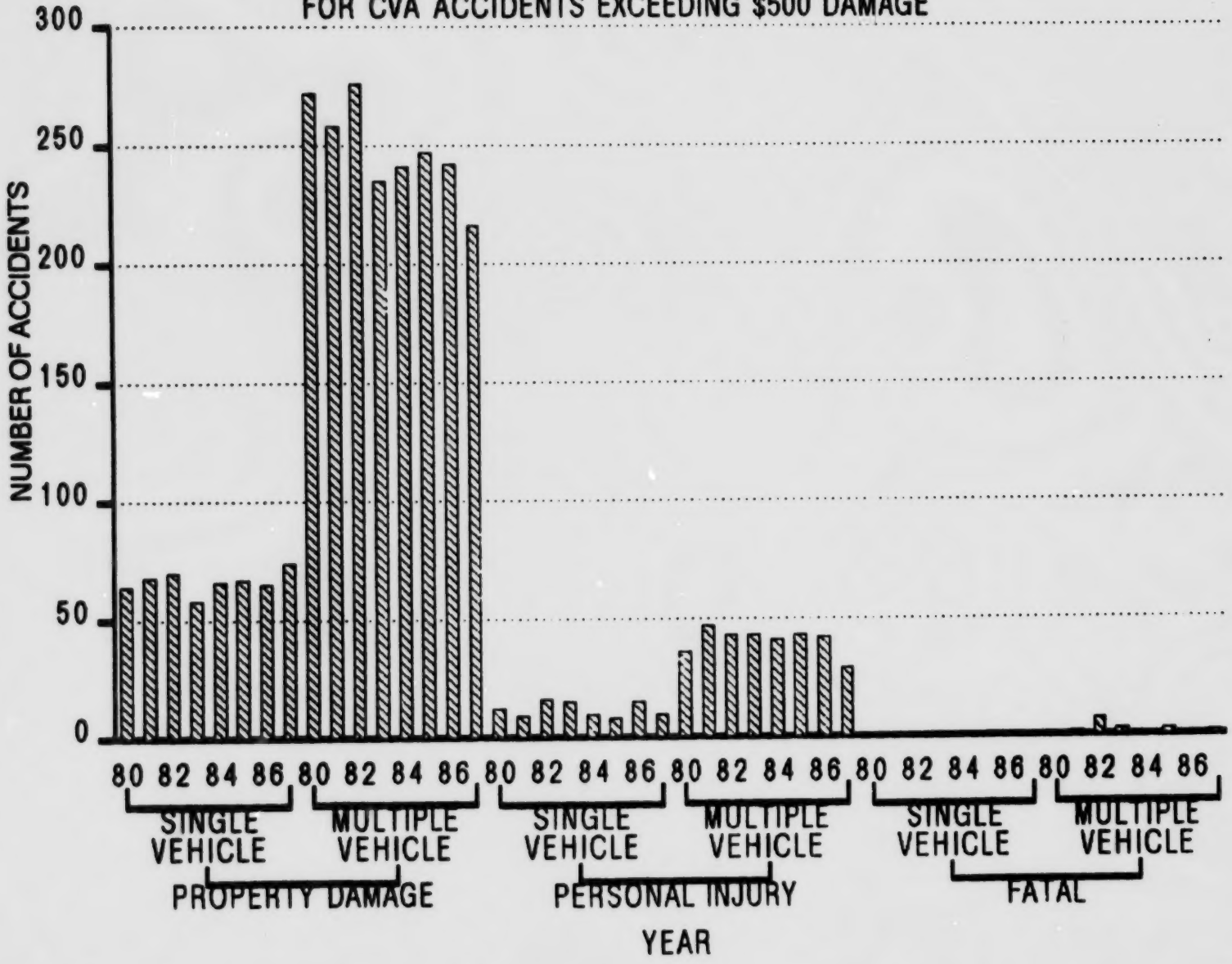


TABLE 12

NUMBER OF MULTIPLE VEHICLE ACCIDENTS BY LIGHT CONDITION BY YEAR FOR CVA ACCIDENTS WITH DAMAGES GREATER THAN $500

YEAR	NUMBER OF ACCIDENTS		
	DAYLIGHT	DARKNESS	TOTAL
1980	264	44	308
1981	255	52	307
1982	292	34	326
1983	243	38	281
1984	248	34	282
1985	259	29	288
1986	240	42	282
1987	220	23	243
TOTAL	2021	296	2317

NOTE:
1.) DAYLIGHT INCLUDES DUSK/DAWN HOURS.
2.) DARKNESS INCLUDES ACCIDENTS WITH ARTIFICIAL LIGHTING.
3.) 19 ACCIDENTS NOT INCLUDED DUE TO MISSING DATA.
4.) TOTAL CASES = 2336
5.) 1986 AND 1987 DATA ARE FROM JUNE 1st OF THE YEAR INDICATED UNTIL MAY 31st OF THE FOLLOWING YEAR.

FIGURE 11

NUMBER OF CVA ACCIDENTS

MULTIPLE VEHICLE, EXCEEDING $500 DAMAGES

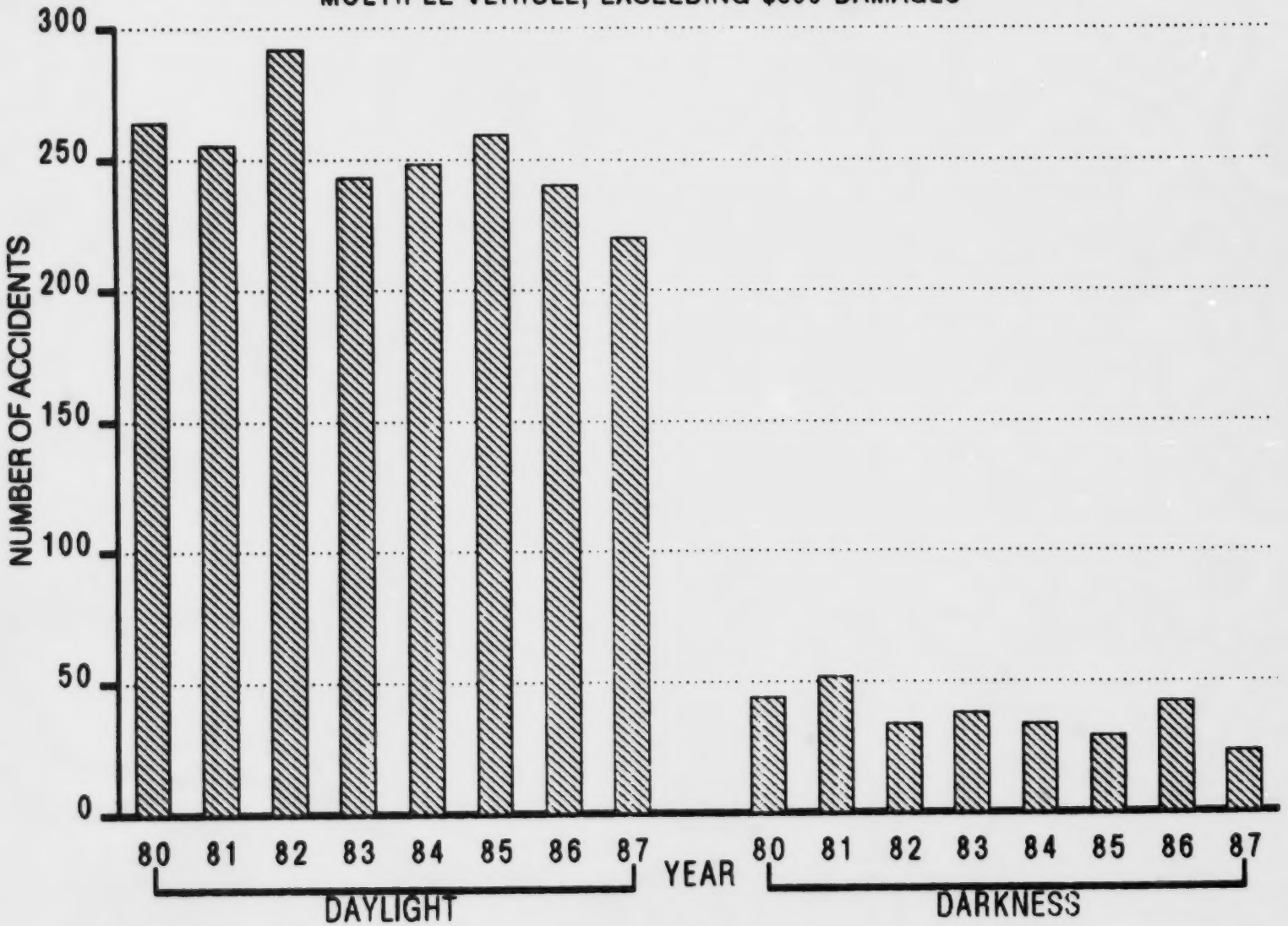


Table 13 and Figure 12 illustrate the total estimated costs of CVA multiple-vehicle accidents with damages exceeding $500 by daylight and darkness by year. As noted, there is considerable variability in costs for both daylight and darkness accidents with an increasing trend somewhat apparent in the cost of daylight accidents but not in accidents after dark.

Table 14 and Figure 13 summarize the number of multiple-vehicle CVA accidents by severity, for daytime and darkness, by year. Daytime property damage accidents predominate the data.

3.7 PROFILE OF MULTIPLE-VEHICLE, DAYLIGHT CVA ACCIDENTS BY CONFIGURATION

If DRL's do have a positive impact upon either the number, severity or cost of CVA accidents, it would be desirable to identify the type (i.e. configuration) of accidents most affected and the magnitude of this effect. To this end, Table 15 and Figure 14 illustrate the number of multiple-vehicle daylight CVA accidents by configuration by year. Configuration 5 (right-angle), 7 (head-on), 8 (head-on), and 9 (head-on) would be expected to be potentially affected by DRL's.

Table 16 and Figure 15 illustrate the total estimated costs of the above noted accidents, while Table 17 and Figure 16 illustrate the number of accidents by configuration, by severity, by year. Table 18 and Figure 17 illustrate the total estimated cost of multiple-vehicle daylight CVA accidents by severity by year. In all of the tables listed above there is a high variance (due mainly to the small sample size) which tends to hide any observable trends. However, it can be noted from Figure 14 that in three of the four DRL-affected configurations (ie. 5, 7 and 8) there is a decreasing trend in the 1986 and 1987 data.

4.0 STATISTICAL TESTING FOR SIGNIFICANT DIFFERENCES

In determining if DRL's have a statistically significant impact upon the number, cost and severity of CVA accidents, a number of approaches might be taken. These could involve either a controlled experiment or a sampling experiment. The first part of this section describes each of these experimental testing methodologies. The second section describes the actual statistics used in the analysis and the third section presents the results of the statistical testing.

4.1 STATISTICAL APPROACHES IN ASSESSING THE DRL EFFECT

4.1.1 A CONTROLLED EXPERIMENT

The appropriate study design is quite simple if an actual controlled experiment can be performed. In the case of the CVA,

TABLE 13

TOTAL COST OF MULTIPLE VEHICLE CVA ACCIDENTS WITH DAMAGES GREATER THAN $500 BY LIGHT CONDITIONS BY YEAR

YEAR	DAYLIGHT ACCIDENTS			DARKNESS ACCIDENTS		
	NO. OF ACCIDENTS	TOTAL COST ($)	AVERAGE COST ($/veh)	NO. OF ACCIDENTS	TOTAL COST ($)	AVERAGE COST ($/veh)
1980	264	441,258	1,671.4	44	76,800	1,745.5
1981	255	656,511	2,574.6	52	142,820	2,746.5
1982	292	739,218	2,531.6	34	94,270	2,772.6
1983	243	662,407	2,726.0	38	221,300	5,823.7
1984	248	598,131	2,411.8	34	148,940	4,380.6
1985	259	840,081	3,243.6	29	79,996	2,758.5
1986	240	790,193	3,292.5	42	186,621	4,443.4
1987	220	758,120	3,446.0	23	88,928	3,866.4
TOTAL	2,021	5,485,919		296	1,039,675	

NOTE:
1.) DAYLIGHT INCLUDES DUSK/DAWN HOURS.
2.) DARKNESS INCLUDES ACCIDENTS OCCURING UNDER ARTIFICIAL LIGHTING.
3.) 19 ACCIDENTS NOT INCLUDED DUE TO MISSING DATA.
4.) TOTAL CASES = 2336
5.) 1986 AND 1987 DATA ARE FROM JUNE 1st OF THE YEAR INDICATED UNTIL MAY 31st OF THE FOLLOWING YEAR.

FIGURE 12

TOTAL COST OF CVA ACCIDENTS

MULTIPLE VEHICLE, EXCEEDING $500 DAMAGE

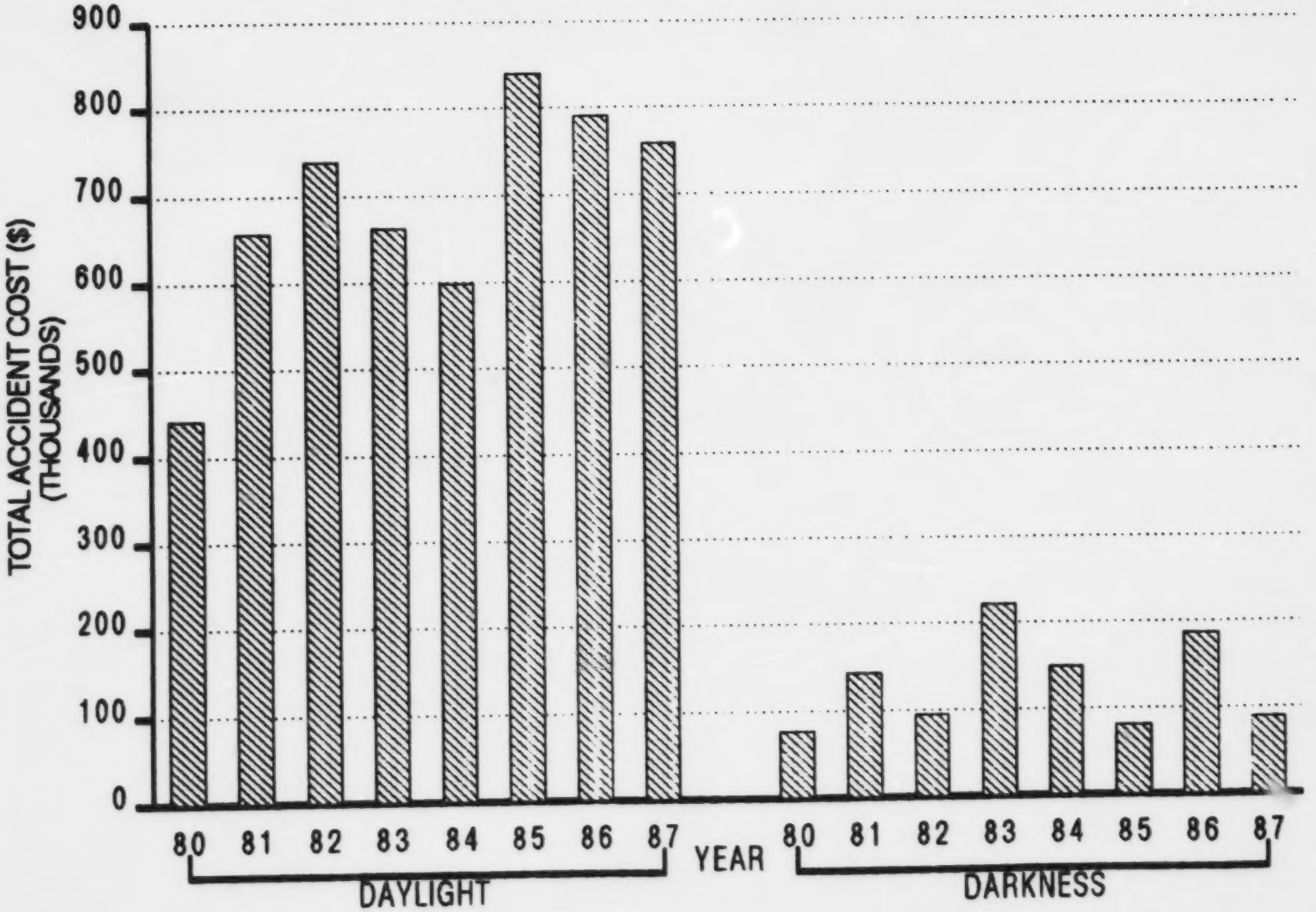


TABLE 14

NUMBER OF CVA ACCIDENTS BY SEVERITY BY LIGHT CONDITIONS BY YEAR
FOR MULTIPLE VEHICLE ACCIDENTS WITH DAMAGES GREATER THAN $500

YEAR	PROPERTY DAMAGE		PERSONAL INJURY		FATALITY		TOTAL
	DAYLIGHT	DARKNESS	DAYLIGHT	DARKNESS	DAYLIGHT	DARKNESS	
1980	232	40	32	4	0	0	308
1981	213	45	42	5	0	2	307
1982	246	30	40	3	6	1	326
1983	202	33	38	5	3	0	281
1984	212	29	36	5	0	0	282
1985	220	23	36	6	3	0	288
1986	204	35	36	7	0	0	282
1987	193	19	26	3	1	1	243
TOTAL	1,722	254	286	38	13	4	2,317

NOTE:
1.) DAYLIGHT INCLUDES DUSK/DAWN HOURS.
2.) DARKNESS INCLUDES ACCIDENTS OCCURING UNDER ARTIFICIAL LIGHTING.
3.) 19 ACCIDENTS NOT INCLUDED DUE TO MISSING DATA.
4.) TOTAL CASES = 2336
5.) 1986 AND 1987 DATA ARE FROM JUNE 1st OF THE YEAR INDICATED UNTIL MAY 31st OF THE FOLLOWING YEAR.

FIGURE 13

SEVERITY OF CVA ACCIDENTS

MULTIPLE VEHICLE, EXCEEDING $500 DAMAGE

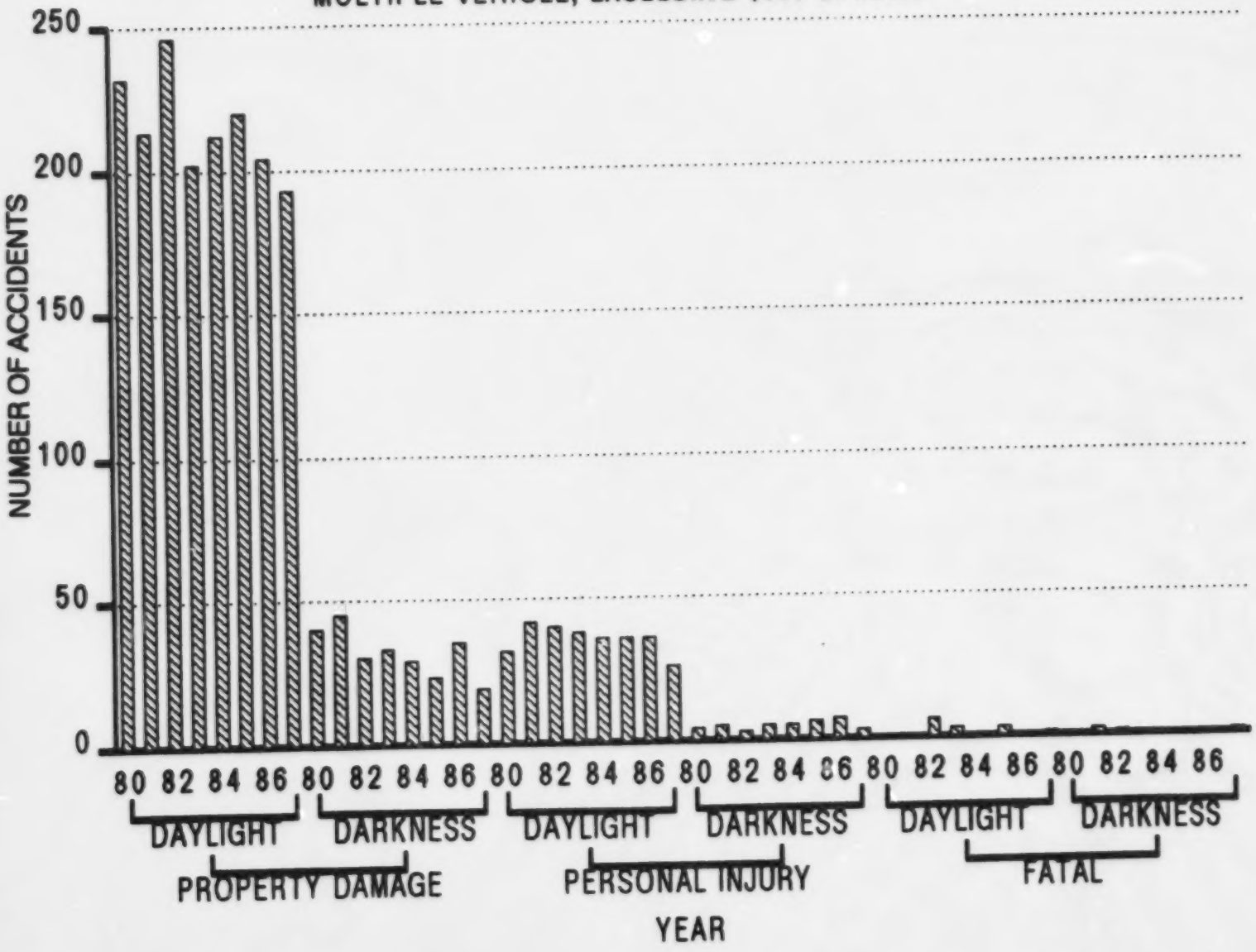


TABLE 15

NUMBER OF MULTIPLE VEHICLE, DAYLIGHT, CVA ACCIDENTS BY YEAR
BY CONFIGURATION FOR ACCIDENTS WITH DAMAGES GREATER THAN $500

YEAR	ACCIDENT CONFIGURATION									
	REAR END 4	RT ANGLE 5	SIDSWIPE 6	HEAD ON 7	HEAD ON 8	HEAD ON 9	SIDSWIPE 10	SIDSWIPE 11	OTHER 12	TOTAL
1980	68	90	8	16	10	13	16	8	35	264
1981	65	83	9	10	4	18	26	7	33	255
1982	93	76	8	16	9	24	15	9	42	292
1983	66	69	12	12	11	22	12	10	29	243
1984	61	87	10	7	5	13	14	8	43	248
1985	64	72	15	10	9	11	17	9	52	259
1986	61	63	14	6	4	18	22	18	34	240
1987	70	58	11	5	2	18	10	10	36	220
TOTAL	548	598	87	82	54	137	132	79	304	2021

NOTE: 1.) TOTAL CASES = 2021

2.) CONFIGURATION DESCRIPTIONS

4 - REAR END
5 - RIGHT ANGLE
6 - VEHICLE OVERTAKING IN PASSING LANE
7 - APPROACHING VEHICLES
8 - HEAD ON
9 - VEHICLE SWERVING TO AVOID HEAD ON COLLISION
10 - VEHICLE SWERVING INTO PASSING LANE
11 - VEHICLE SWERVING FROM PASSING LANE
12 - OTHER (INCLUDES ACCIDENTS WHERE MORE THAN TWO VEHICLES ARE INVOVLED)

FIGURE 14(A)

CVA ACCIDENTS BY CONFIGURATION (DRL AFFECTED)

MULTI-VEHICLE, DAYLIGHT, >$500 DAMAGE

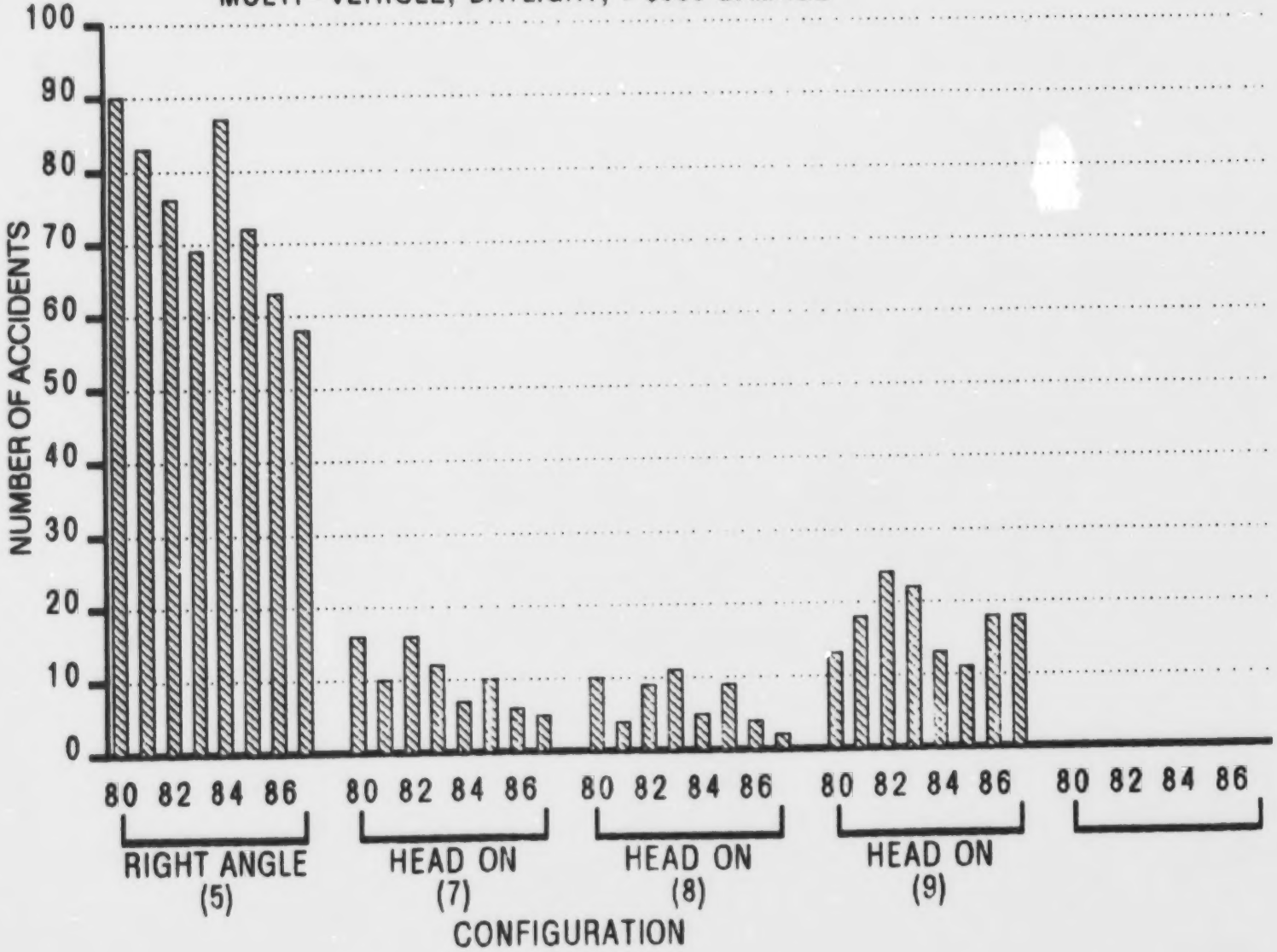


FIGURE 14(B)

CVA ACCIDENTS BY CONFIGURATION (NON-DRL AFFECTED)

MULTI-VEHICLE, DAYLIGHT, >$500 DAMAGE

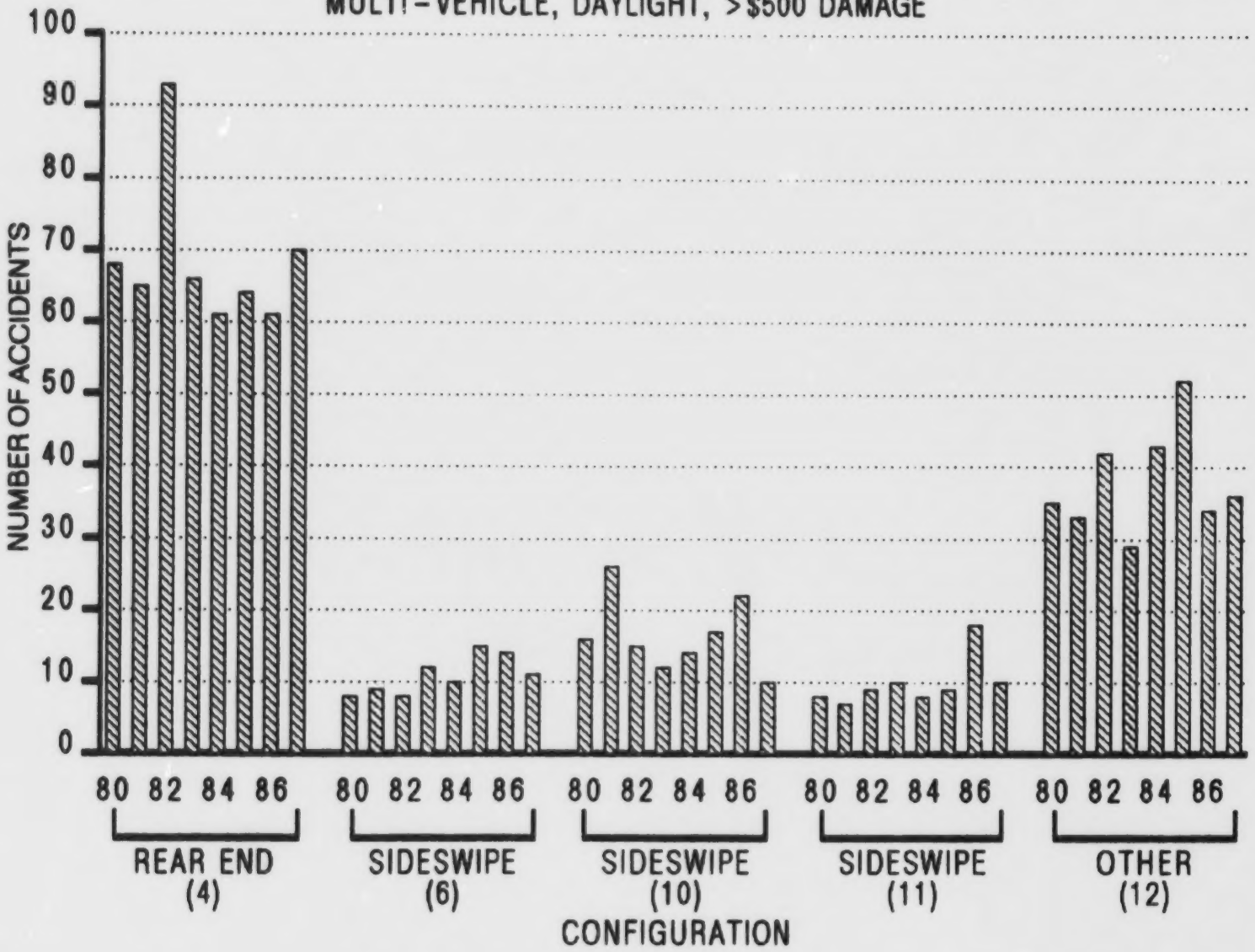


TABLE 16

TOTAL AND AVERAGE COST FOR MULTIPLE VEHICLE, DAYLIGHT, CVA ACCIDENTS BY YEAR BY CONFIGURATION FOR ACCIDENTS WITH DAMAGES GREATER THAN $500

YEAR	TOTAL AND MEAN COST									
	REAR END 4	RT ANGLE 5	SIDSWIPE 6	HEAD ON 7	HEAD ON 8	HEAD ON 9	SIDSWIPE 10	SIDSWIPE 11	OTHER 12	TOTAL
1980	119,975 (1,764)	148,435 (1,649)	12,525 (1,565)	31,330 (1,958)	23,200 (2,320)	21,350 (1,642)	24,450 (1,528)	16,300 (2,037)	43,693 (1,248)	441,258
1981	279,226 (4,296)	170,220 (2,051)	13,750 (1,528)	20,990 (2,099)	7,350 (1,838)	49,300 (2,739)	41,265 (1,587)	7,735 (1,105)	66,675 (2,020)	656,521
1982	257,390 (2,768)	199,775 (2,629)	13,700 (1,713)	53,950 (3,372)	27,000 (3,000)	57,950 (2,415)	43,528 (2,902)	9,350 (1,039)	76,575 (1,823)	739,218
1983	168,132 (2,548)	189,350 (2,744)	14,850 (1,238)	34,700 (2,892)	62,900 (5,718)	56,200 (2,555)	24,300 (1,950)	14,850 (1,485)	98,025 (3,380)	663,307
1984	125,598 (2,059)	261,196 (3,002)	22,535 (2,253)	17,650 (2,521)	18,700 (3,740)	39,850 (3,065)	28,200 (2,014)	13,112 (1,639)	71,290 (1,658)	598,131
1985	137,239 (2,144)	223,257 (3,101)	24,634 (1,642)	93,300 (9,330)	57,165 (6,352)	55,335 (5,030)	99,800 (5,871)	12,450 (1,383)	109,901 (2,154)	813,081
1986	145,359 (2,383)	229,081 (3,636)	29,619 (2,116)	27,200 (4,533)	37,900 (9,475)	47,600 (2,644)	38,736 (1,761)	155,300 (8,628)	79,398 (2,335)	790,193
1987	404,881 (5,784)	173,904 (2,998)	19,676 (1,789)	19,650 (3,930)	2,500 (1,250)	47,343 (2,630)	15,412 (1,542)	12,091 (1,209)	62,663 (1,843)	758,120
TOTAL	1,637,800	1,595,218	151,289	298,770	236,715	374,928	315,691	241,188	608,220	5,459,819

NOTE: 1.) TOTAL CASES = 2021
2.) MEAN COST IN BRACKETS.
3.) CONFIGURATION DESCRIPTIONS

4 - REAR END
5 - RIGHT ANGLE
6 - VEHICLE OVERTAKING IN PASSING LANE
7 - APPROACHING VEHICLES
8 - HEAD ON
9 - VEHICLE SWERVING TO AVOID HEAD ON COLLISION
10 - VEHICLE SWERVING INTO PASSING LANE
11 - VEHICLE SWERVING FROM PASSING LANE
12 - OTHER (INCLUDES ACCIDENTS WHERE MORE THAN TWO VEHICLES ARE INVOVLED)

FIGURE 15(A)

CVA ACCIDENT COST BY CONFIGURATION (DRL AFFECTED)

MULTIPLE VEHICLE, DAYLIGHT, >$500 DAMAGE

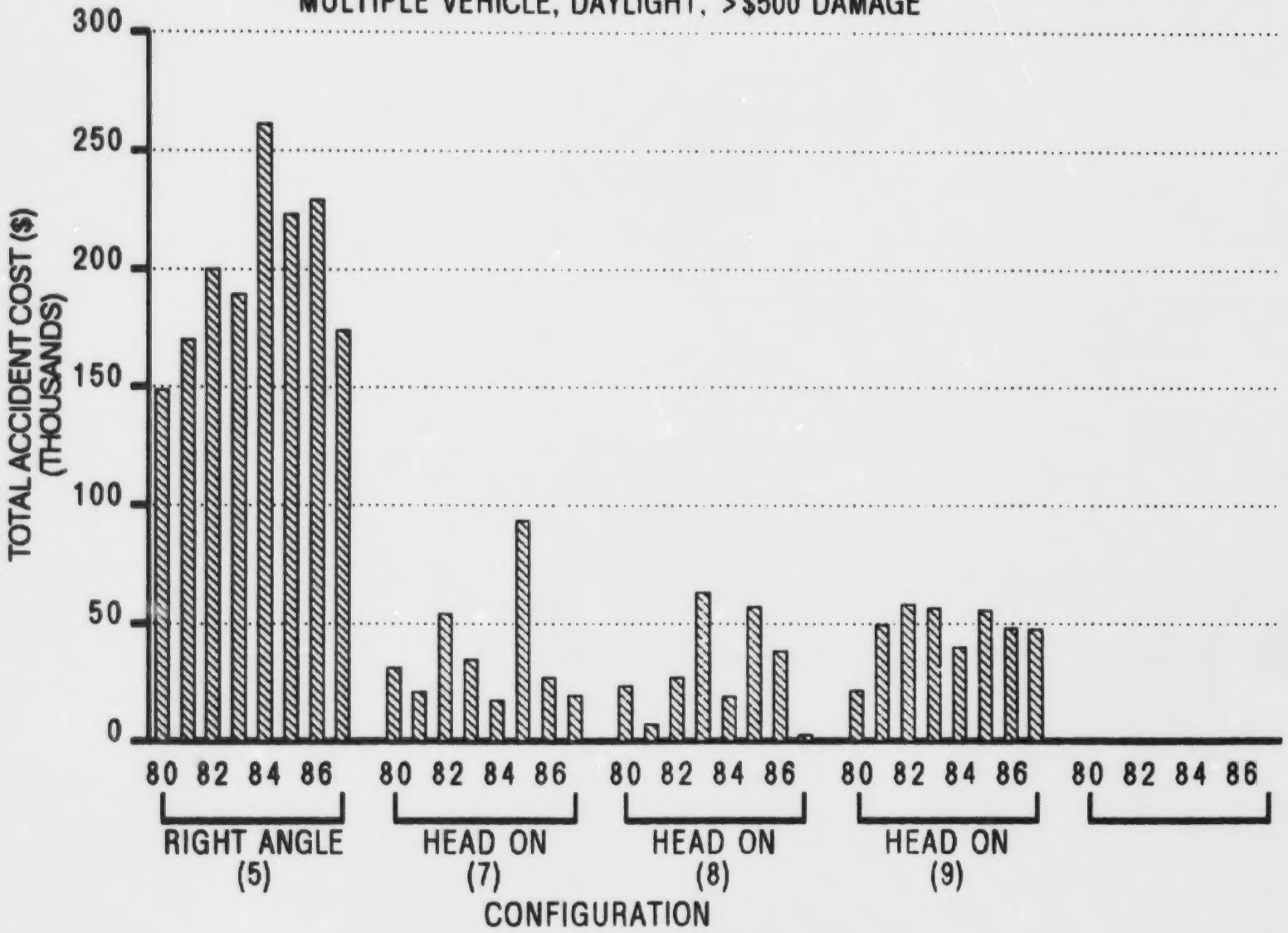


FIGURE 15(B)

CVA ACCIDENT COST BY CONFIGURATION (NON-DRL AFFECTED)

MULTIPLE VEHICLE, DAYLIGHT, >$500 DAMAGE

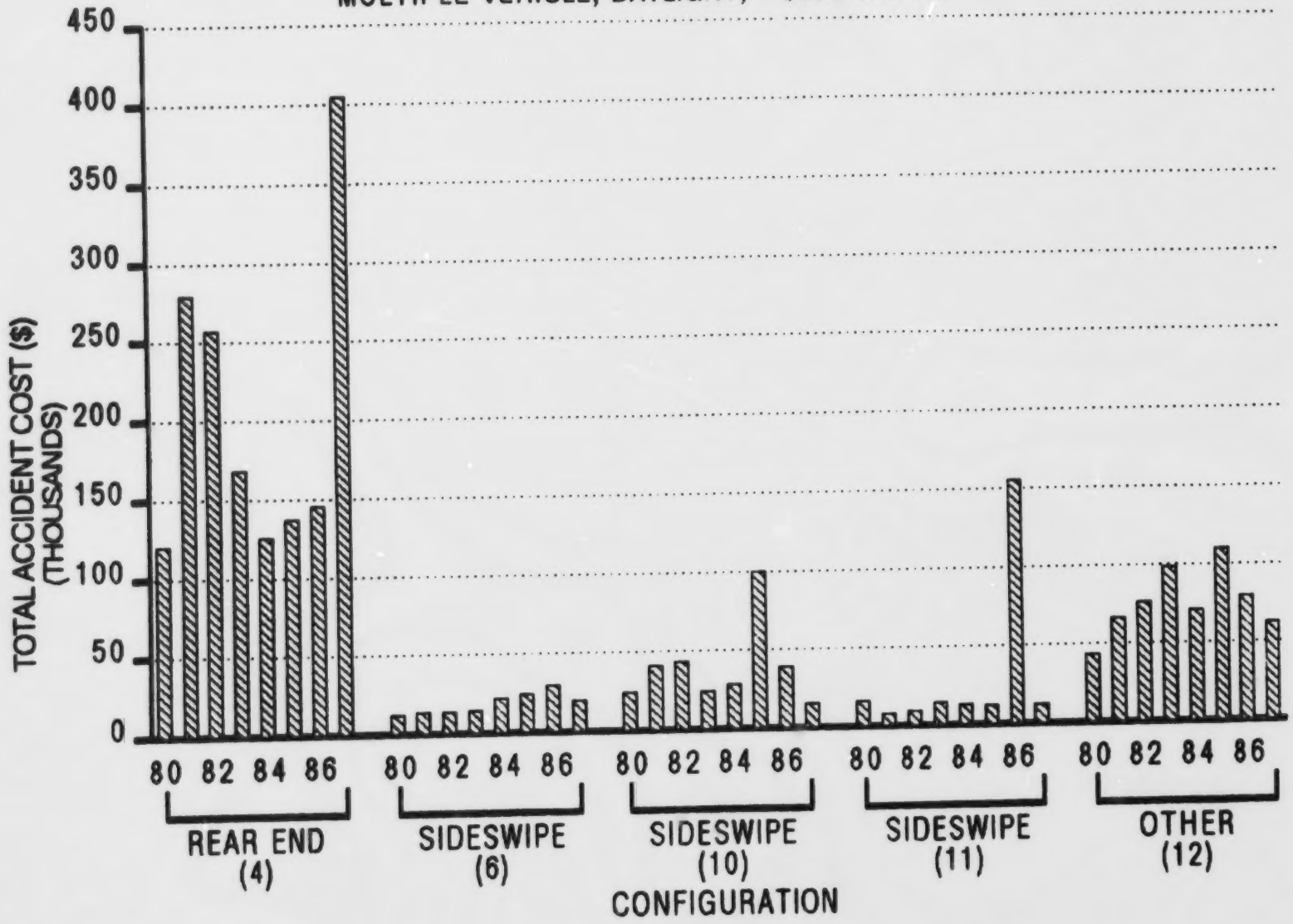


TABLE 17

NUMBER OF MULTIPLE VEHICLE DAYLIGHT CVA ACCIDENTS BY CONFIGURATION, BY SEVERITY, BY YEAR FOR ACCIDENTS WITH DAMAGES GREATER THAN $500

YEAR	4 (REAR END)				5 (RT ANGLE)				6 (SIDESWIPE)				7 (HEAD ON)				8 (HEAD ON)				9 (HEAD ON)			
	A	B	C	TOTAL	A	B	C	TOTAL	A	B	C	TOTAL	A	B	C	TOTAL	A	B	C	TOTAL	A	B	C	TOTAL
1980	55	13	0	68	80	10	0	90	7	1	0	8	16	0	0	16	8	2	0	10	12	1	0	13
1981	44	21	0	65	76	7	0	83	8	1	0	9	8	2	0	10	3	1	0	4	15	3	0	18
1982	76	16	1	93	63	11	2	76	7	1	0	8	13	3	0	16	6	3	0	9	19	3	2	24
1983	57	9	0	66	54	14	1	69	11	1	0	12	10	2	0	12	6	3	2	11	19	3	0	22
1984	47	14	0	61	74	13	0	87	9	1	0	10	6	1	0	7	3	2	0	5	11	2	0	13
1985	53	11	0	64	64	7	1	72	14	1	0	15	8	1	1	10	6	2	1	9	7	4	0	11
1986	50	11	0	61	52	11	0	63	14	0	0	14	4	2	0	6	3	1	0	4	13	5	0	18
1987	56	14	0	70	50	7	1	58	10	1	0	11	4	1	0	5	2	0	0	2	17	1	0	18
TOTAL	438	109	1	548	513	80	5	598	80	7	0	87	69	12	1	82	37	14	3	54	113	22	2	137

NOTE:
1.) 1 ACCIDENT IS NOT INCLUDED DUE TO MISSING DATA.
2.) TOTAL CASES = 2021
3.) CONFIGURATION DESCRIPTIONS
- 4 - REAR END
- 5 - RIGHT ANGLE
- 6 - VEHICLE OVERTAKING IN PASSING LANE
- 7 - APPROACHING VEHICLES
- 8 - HEAD ON
- 9 - VEHICLE SWERVING TO AVOID HEAD ON COLLISION
- 10 - VEHICLE SWERVING INTO PASSING LANE
- 11 - VEHICLE SWERVING FROM PASSING LANE
- 12 - OTHER (INCLUDES ACCIDENTS WHERE MORE THAN TWO VEHICLES ARE INVOVLED)

4.) LEGEND: A - PROPERTY DAMAGE
B - PERSONAL INJURY
C - FATALITY

TABLE 17 (cont'd)

NUMBER OF MULTIPLE VEHICLE DAYLIGHT CVA ACCIDENTS BY CONFIGURATION, BY SEVERITY, BY YEAR FOR ACCIDENTS WITH DAMAGES GREATER THAN $500

YEAR	10 (SIDESWIPE)				11 (SIDESWIPE)				12 (OTHER)				TOTAL			
	A	B	C	TOTAL	A	B	C	TOTAL	A	B	C	TOTAL	A	B	C	TOTAL
1980	12	4	0	16	7	1	0	8	35	0	0	35	232	32	0	264
1981	24	2	0	26	7	0	0	7	28	5	0	33	213	42	0	255
1982	13	1	1	15	9	0	0	9	40	2	0	42	246	40	6	292
1983	11	1	0	12	10	0	0	10	24	5	0	29	202	38	3	243
1984	14	0	0	14	8	0	0	8	40	3	0	43	212	36	0	248
1985	14	3	0	17	9	0	0	9	45	6	0	51	220	35	3	258
1986	22	0	0	22	17	1	0	18	29	5	0	34	204	36	0	240
1987	8	2	0	10	10	0	0	10	34	0	0	34	193	26	1	220
TOTAL	118	13	1	132	77	2	0	79	275	26	0	301	1722	285	13	2020

NOTE:
1.) 1 ACCIDENT IS NOT INCLUDED DUE TO MISSING DATA.
2.) TOTAL CASES = 2021
3.) CONFIGURATION DESCRIPTIONS
- 4 - REAR END
- 5 - RIGHT ANGLE
- 6 - VEHICLE OVERTAKING IN PASSING LANE
- 7 - APPROACHING VEHICLES
- 8 - HEAD ON
- 9 - VEHICLE SWERVING TO AVOID HEAD ON COLLISION
- 10 - VEHICLE SWERVING INTO PASSING LANE
- 11 - VEHICLE SWERVING FROM PASSING LANE
- 12 - OTHER (INCLUDES ACCIDENTS WHERE MORE THAN TWO VEHICLES ARE INVOVLED)

4.) LEGEND: A - PROPERTY DAMAGE
B - PERSONAL INJURY
C - FATALITY

FIGURE 16(A)

ACCIDENTS BY CONFIGURATION AND SEVERITY (DRL AFFECTED)

MULTIPLE VEHICLE, DAYLIGHT, >$500 DAMAGE

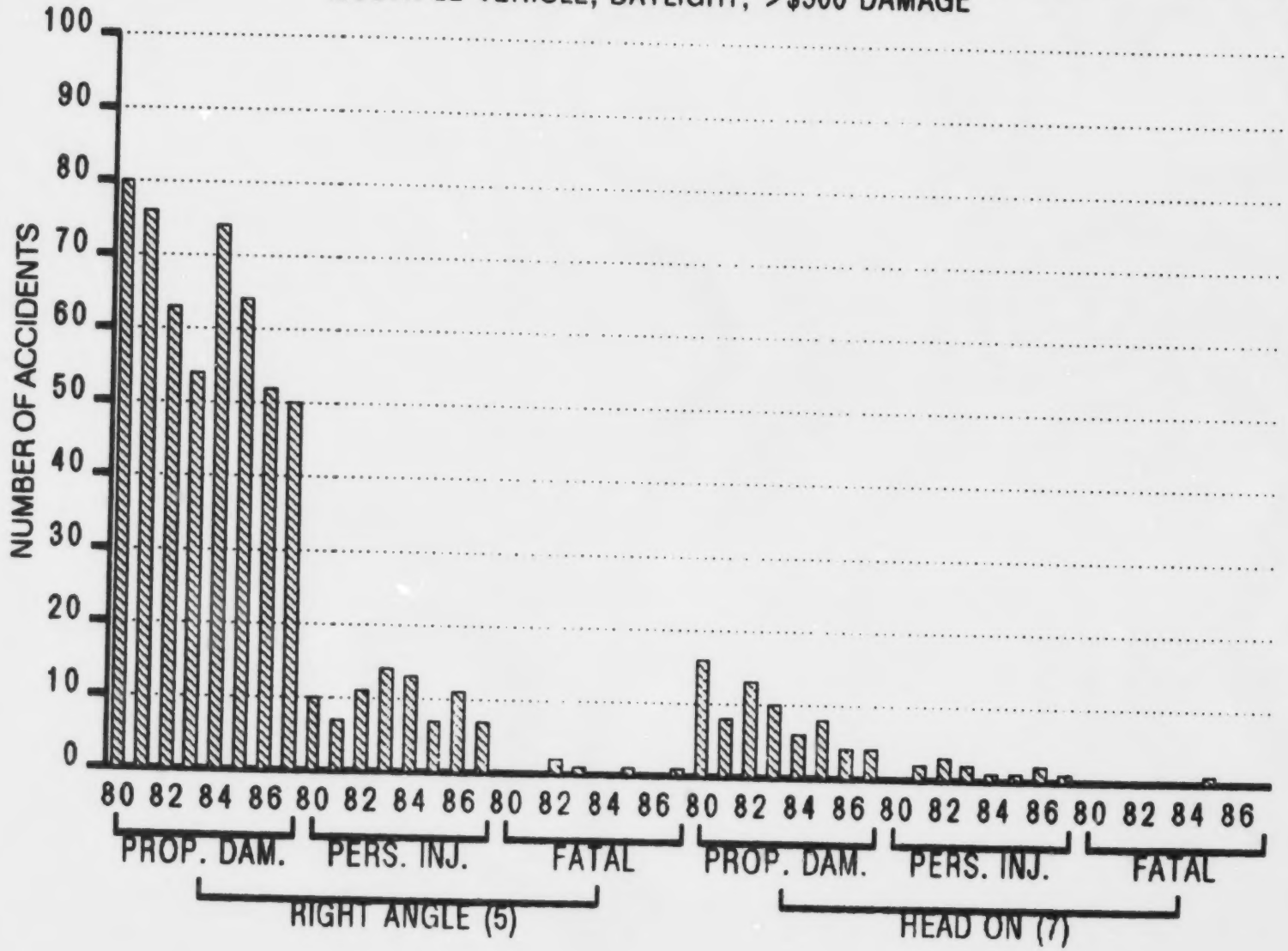


FIGURE 16(B)

ACCIDENTS BY CONFIGURATION AND SEVERITY (DRL AFFECTED)

MULTIPLE VEHICLE, DAYLIGHT, >$500 DAMAGE

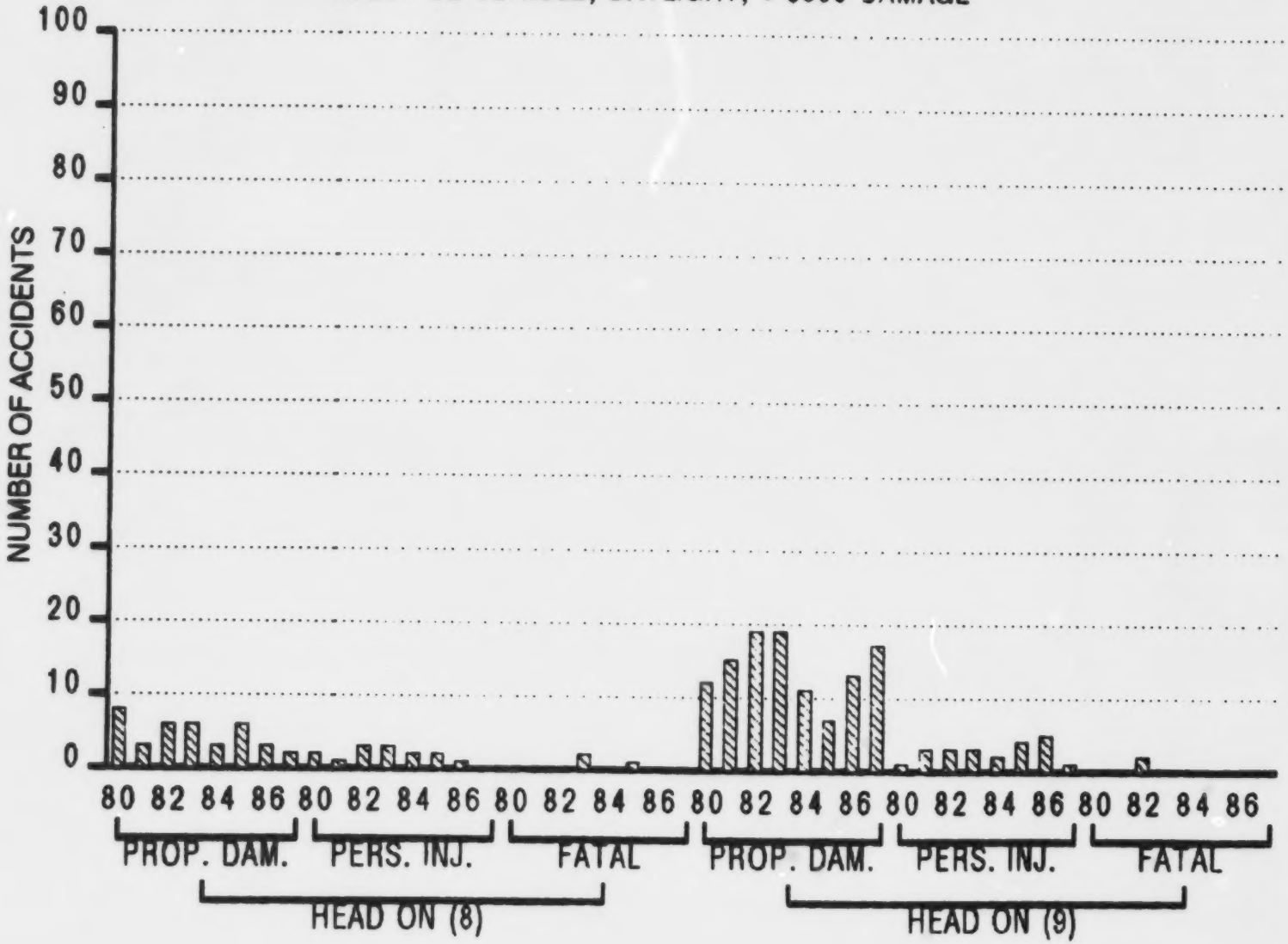


FIGURE 16(C)

ACCIDENTS BY CONFIGURATION AND SEVERITY (NON-DRL AFFECTED)

MULTIPLE VEHICLE, DAYLIGHT, >$500 DAMAGE

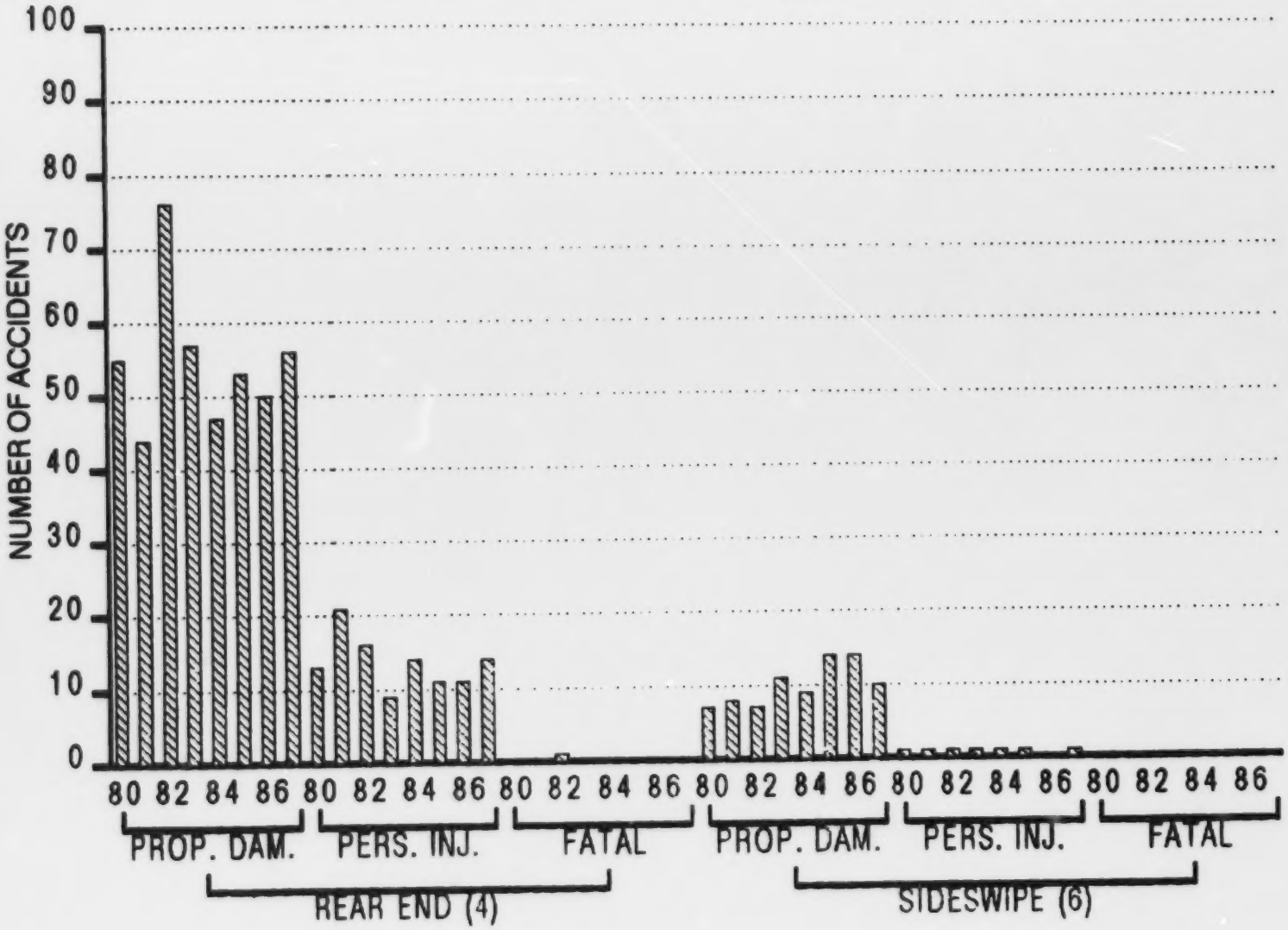


FIGURE 16(D)

ACCIDENTS BY CONFIGURATION AND SEVERITY (NON-DRL AFFECTED)

MULTIPLE VEHICLE, DAYLIGHT, >$500 DAMAGE

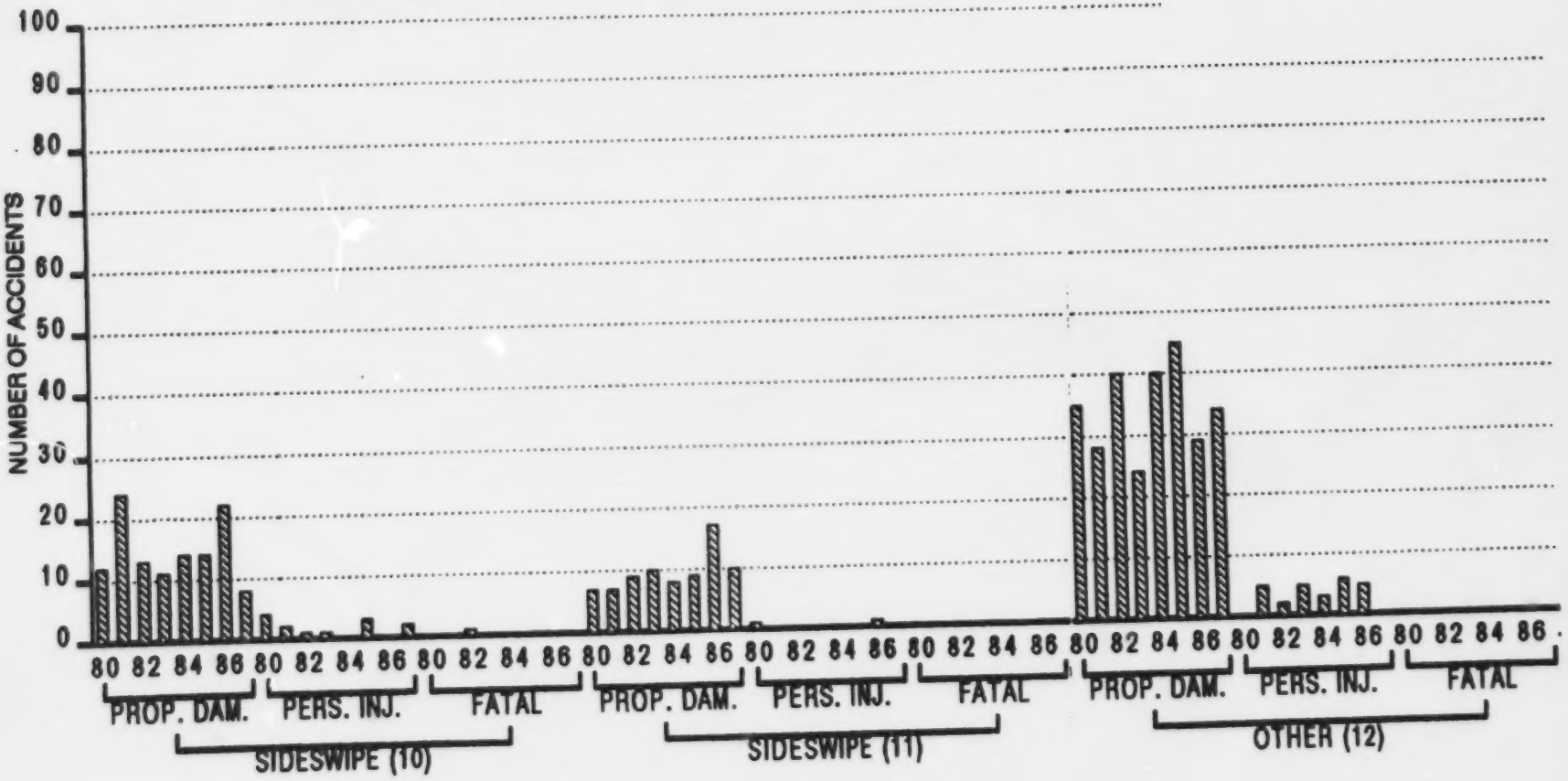


TABLE 18

TOTAL COST OF MULTIPLE VEHICLE DAYLIGHT CVA ACCIDENTS BY SEVERITY, BY YEAR FOR ACCIDENTS WITH DAMAGES GREATER THAN $500

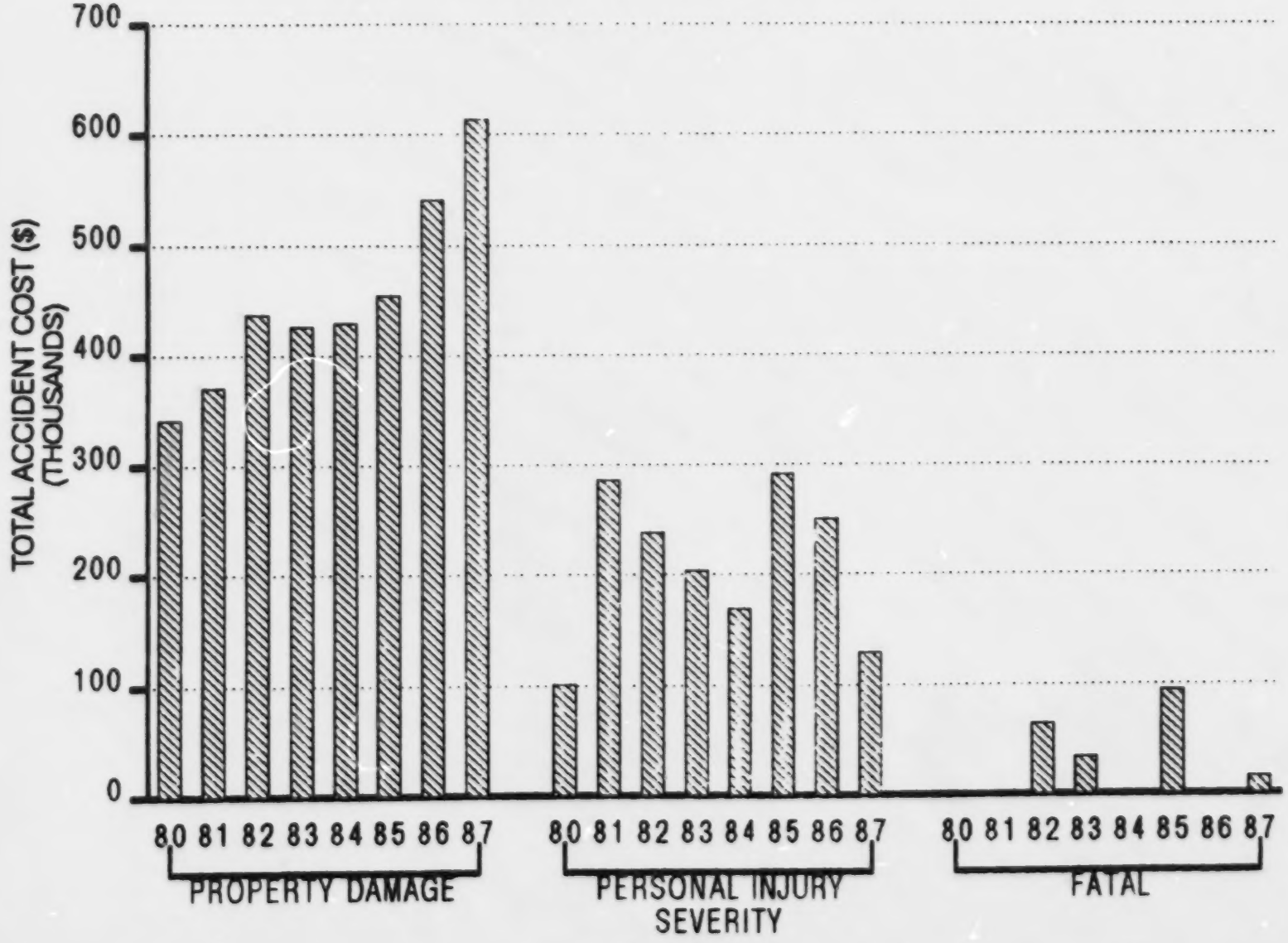
YEAR	TOTAL COST ($)						TOTAL
	PROPERTY DAMAGE		PERSONAL INJURY		FATALITY		
	TOTAL	AVERAGE	TOTAL	AVERAGE	TOTAL	AVERAGE	
1980	340,908	1,469	100,350	3,136	0	0	441,258
1981	370,871	1,741	285,640	6,801	0	0	656,511
1982	436,893	1,776	238,325	5,958	64,000	10,667	739,218
1983	425,757	2,108	203,650	5,359	33,000	11,000	662,407
1984	428,981	2,024	169,150	4,699	0	0	598,131
1985	454,156	2,064	291,825	8,106	94,100	31,367	840,081
1986	540,391	2,649	249,802	6,939	0	0	790,193
1987	613,740	3,180	129,380	4,976	15,000	15,000	758,120
TOTAL	3,611,697		1,668,122		206,100		5,485,919

1.) 1 ACCIDENT IS NOT INCLUDED DUE TO MISSING DATA.
2.) TOTAL CASES = 2021

FIGURE 17

TOTAL CVA ACCIDENT COST BY SEVERITY

MULTIPLE VEHICLE, DAYLIGHT, DAMAGES >$500



if it would be possible to temporarily disconnect a random fraction of the DRL's for limited periods of time during the one to two year test period, then a truly controlled experiment could be performed with formal control and test groups, and we would not be required to rely on sampling of different universes to obtain control data. The experiment would have the most chance of any possible study design for obtaining the least "noisy" data and would therefore be the most likely method for statistically detecting with confidence an effect of DRL's on accident rates.

The experiment would be performed in the following way. The CVA fleet would be randomly assigned to two groups: those with DRL's and those with the DRL's temporarily disabled. Then, if possible, drivers should be randomly assigned to vehicles. (This avoids the possibility that certain types of drivers would choose to drive certain types of vehicles, causing what is called "sample selection bias" which could completely mask any real DRL effect.) All data on the mix of vehicle and driver characteristics would be retained, as well as data on accident characteristics for those accidents that occur during the experiment.

Finally, if at all possible, each vehicle should have the DRL enabled and disabled for some portion of the experiment. For instance, a vehicle that has DRL for the winter of the first year should be made non-DRL in the next summer and next winter, then DRL again for the second summer of a two year period. Thus each vehicle/driver combination would be with DRL and without DRL for both seasons, and during both years. This last step of the experiment allows one to better control for time trends, and for residual differences in the randomly assigned test and control groups. In effect, each vehicle/driver combination would be able to serve in part as its own control.

The above experimental design is recognized as the best possible analysis of potential benefits of DRL's. However, an actual experiment of this sort is precluded, due to the associated costs and implementation constraints. (It is highly unlikely to be able to undertake the above noted experiment because some drivers of vehicles with DRL's disconnected would turn on the headlights anyway. This would dilute the effect of DRL's and negate the experiment. Further, you could hardly instruct a driver not to use his headlights during daylight hours given we think it is safer to use them.)

The best sampling alternative would therefore be to use the CVA-fleet accident experience in years previous to the DRL implementation as the control data. The following describes the sampling procedure approach and provides a discussion of the reasoning behind our recommendation for this approach.

4.1.2 A SAMPLING PROCEDURE TO ASSESS THE DRL EFFECT

There are two general approaches possible for obtaining a control group if a controlled experiment is unacceptable (7). One method is to use pre-DRL CVA fleet outcomes as the control. For instance, the number of CVA daylight accidents exceeding $500 in the years before the DRL's were installed would be the control group outcome. This would be compared against the number of CVA daylight accidents exceeding $500 in the years when DRL's are in effect. This is called a time-series approach. The other method is to identify a control group outside of the CVA fleet for the same years in which data is collected for the CVA test group. For instance, the control outcome might be the accident rate in a group of cars sampled from the 1987 non-CVA population of cars which do not have DRL's. This would then be compared to the accident rate in the same year for CVA cars that are equipped with DRL's. This method is called a cross-section approach.

i). The Cross-Section Approach

The cross-section approach has the advantage of allowing the study to collect the exact data desired for explanatory variables because the study can be designed before data is collected. The researcher is thus not limited to using only those explanatory data which were historically collected. However, there are numerous difficulties with a cross-section approach. First, a good control group would be difficult to identify because of the many factors which affect the general driving skills and risks of different drivers and types of cars. The CVA group is a specific mix of cars, with a specific set of uses and a specific type of driver (i.e., a non-owner who is driving on the job). Any non-CVA control group would probably reflect different characteristics, which would require many additional explanatory variables to account for these differences. Even with the additional variables, there may remain an insurmountable amount of noise in the results. It would be very difficult to statistically identify difference due to DRL's. Further, because the "Lights On for Life" program is affecting the fraction of cars with DRL's in the non-CVA car population, the potential magnitude of the DRL effect between the control and test group is diminished relative to that which would be observed with a control group with no DRL's. The smaller expected effect makes it even less likely that a cross-section analysis will be able to infer any significant DRL effect.

ii). The Time-Series Approach

The use of a time-series approach avoids some of the problems associated with cross-section control groups. First, the general characteristics of the CVA fleet over time is likely to be more stable than they would be between non-CVA and CVA groups. Second, there will be less opportunity for sampling errors, since

the entire universe of accidents can be used for estimation purposes for both the control and test groups. A non-CVA control group by contrast could only be a sample of the potential control universe, and use of a subset can lead to sampling errors in the accident rates and costs that are attributed to that universe.

The time-series approach is therefore the closest study design possible to that of an actual controlled experiment. Confounding noise will then come from only two sources. One source is possible sample selection bias if drivers were not randomly assigned to vehicles in either one of the two time periods. This would be difficult to control for if records were not kept of which drivers drove which vehicles in the past. The other source of noise in a time-series approach is time trends in accident rates or severity. For instance, as car densities increase, the accident rates change. If data is obtained on accident rates from more than a brief period back, and if there has been a trend in traffic densities, then the earlier periods will tend to have different rates due to factors other than adding DRL's.

If time trends exist in the data, these trends must be accounted for if the DRL effect is to be identified statistically with a time-series sampling approach. There are several ways to do this. The most appropriate way would be to seek time trends from the general population for the same types of accidents (i.e. multi-vehicle daylight) over the same time period. Another method is to adjust by taking ratios of multi-vehicle daylight CVA rates to rates for all other CVA accident types during the same time period. This later method was used successfully by Anderson and Nilson in an analysis of data from Finland (4). If time trends are found to exist in the data, we recommend that the analysis correct for trend both ways, since both have advantages and disadvantages. This could be accomplished by first correcting the number of CVA multiple-vehicle daylight accidents per year for any trend in the number of CVA multiple-vehicle daylight accidents in the total vehicle population, and then use a ratio of the total number of CVA multiple-vehicle daytime accidents relative to the total of all other CVA accidents in each time period.

The main problem with the time-series approach tends to be a paucity of data. Data for this study is only available for eight years from which we need to infer a relatively small effect on these rates due to DRL's. The ability to detect the DRL effect will depend on the size of the effect, the natural variability in the data across periods, and the number of sample periods. The review of previous DRL studies indicates that the effect could be expected to be between 7 and 45 percent. This suggests that a statistical investigation can be carried out using a time-series approach. The statistical tools used in this analysis are outlined in the next section.

4.2 STATISTICAL TESTING USING A TIME-SERIES APPROACH

Frequently other studies have used the assumption that accidents are distributed as a Poisson process as the basis for statistical inference. This is equivalent to saying that accidents are random events in time. Thus for any given time interval, there is a predictable distribution on the number of accidents that will occur. The Poisson distribution is described by a single parameter (for a specific time interval), lambda. The expected number of Poisson events in the specific time interval is lambda, and the distribution on how many events will occur is also a function of lambda.

We can test the hypothesis that accidents are Poisson but in fact do not need to rely on this assumption for our analyses. When the expected number of events per time period becomes large, the normal distribution provides a very good approximation of the Poisson (large is usually interpreted to be in the order of 20-30). If we are assessing the number of multi-vehicle/daylight accidents per year, then we would expect lambda to be about 260 (see Table 19). Figure 18 illustrates the data in Table 19. This is large enough to use a normal distribution for hypothesis testing.

The chi-square test allows one to test hypotheses that Poisson-distributed processes have different expected values across two or more sample groups. Similarly, the F-test or Chow test allows such hypothesis testing for normally distributed variables. However, if the comparison is only between two groups, such as before and after DRL's, then both tests can be replaced by a simple difference of means test using the normal distribution.

4.2.1 DIFFERENCE OF MEANS TESTS

We can assess the sampling distributions associated with the difference between mean accident levels before and after DRL's, which we will label $\overline{X1}$ and $\overline{X2}$ as follows:

$\overline{X1} - \overline{X2}$ will be distributed

$$N\left(\mu_1 - \mu_2, \sqrt{\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}}\right)$$

where:
- μ_1 = true mean number of accidents pre-DRL's
- μ_2 = true mean number of accidents post-DRL's
- σ_1^2 = variance of number of accidents pre-DRL's
- σ_2^2 = variance of number of accidents post-DRL's
- n_1 = number of time periods pre-DRL's
- n_2 = number of time periods post-DRL's.

TABLE 19

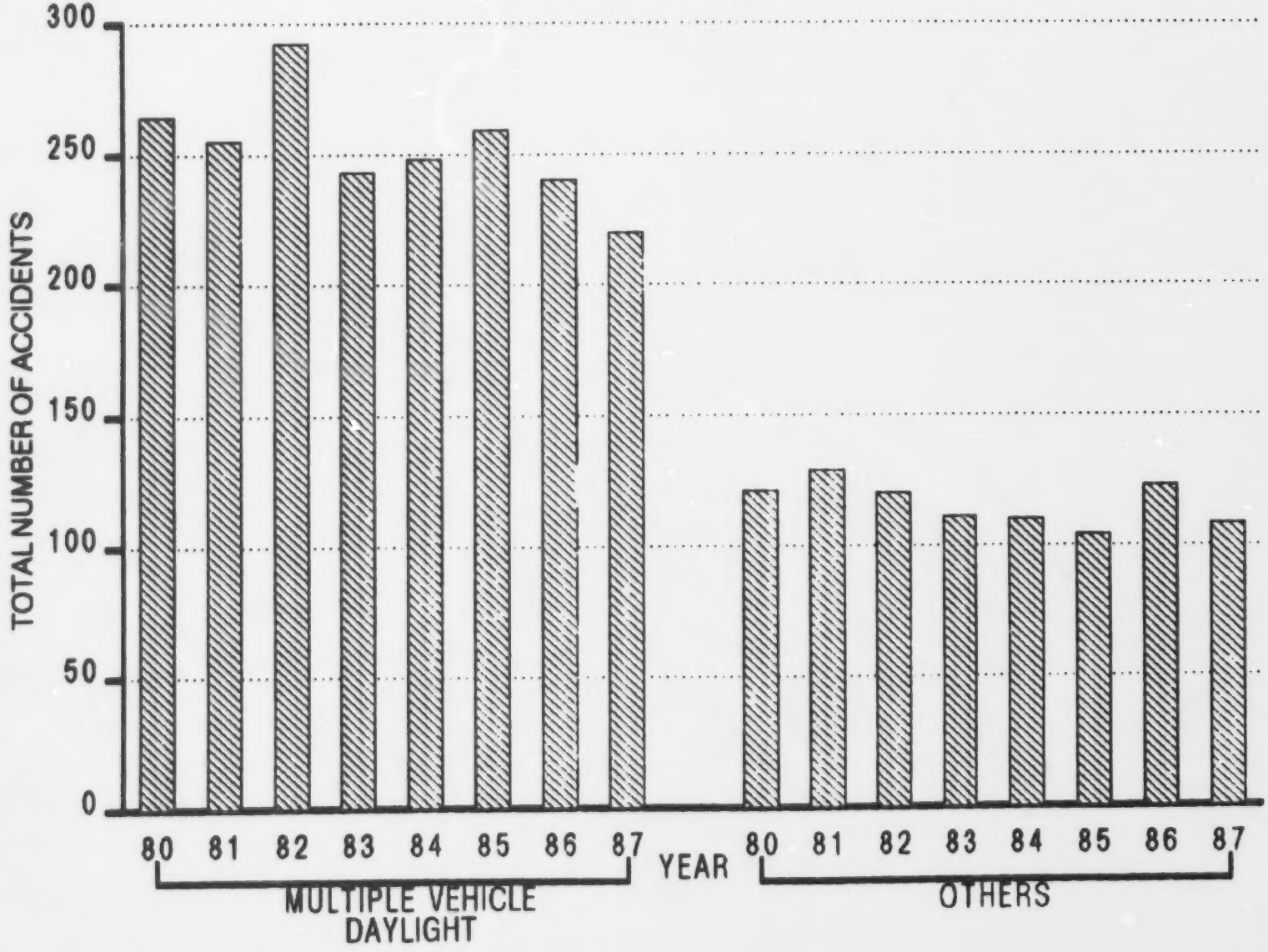
NUMBER OF CVA ACCIDENTS
WITH DAMAGES GREATER THAN $500

YEAR	MULTIPLE VEHICLE DAYLIGHT ACCIDENTS	ALL OTHER (ALL SINGLE VEHICLE, PLUS MULTIPLE VEHICLE DARKNESS ACCIDENTS)
pre-DRL's		
1980	264	121
1981	255	129
1982	292	120
1983	243	111
1984	248	110
1985	259	104
post-DRL's		
1986	240	123
1987	220	108
AVERAGE		
pre-DRL's	260.2	115.8
post-DRL's	230.0	115.5
STANDARD DEVIATION		
pre-DRL's	249.8	69.1
post-DRL's	100.0	56.3

FIGURE 18

NUMBER OF CVA ACCIDENTS

WITH DAMAGES >$500



We can then test the significance of the difference in means based on the Z-statistic, since the sampling distribution has approximately the normal distribution. The Z-statistic is calculated as:

$$Z_{actual} = \frac{\mu_1 - \mu_2}{\sqrt{\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}}}$$

If we hypothesize that $\mu_1 > \mu_2$, then we can use the criteria for the hypothesis test as illustrated in Figure 19 where the α value is the required confidence level for accepting or rejecting the observed difference as real. If, for example, we require a 95% confidence, the Z_α value would be 1.645. If Zactual is greater than Z_α, then we would accept our hypothesis that $\mu_1 > \mu_2$, at the 95% confidence level. If Zactual is less than Z_α, we would reject our hypothesis, concluding that $\mu_1 \not> \mu_2$ at the 95% confidence level. The values for Z_α are obtained from normal probability distribution tables.

4.2.2 PROBABILITY OF DETECTING STATISTICALLY SIGNIFICANT RESULTS

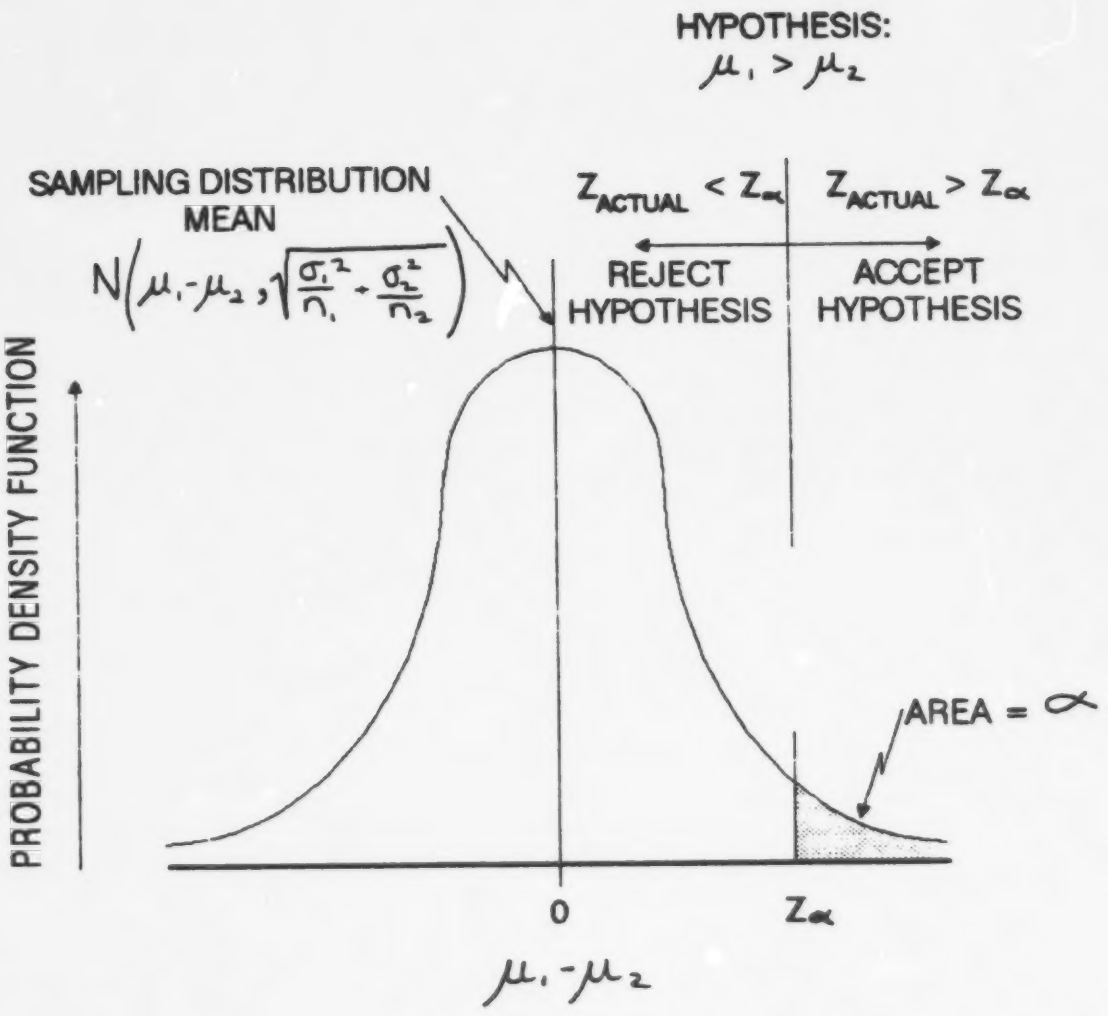
In advance of the actual statistical testing we can predict the success of a statistical investigation, based on the mean (X1) and standard deviation (σ1) of the pre-DRL data and several assumptions.

If DRL's have a 10 percent effect on the mean number of accidents, then we can say that the difference in sample means would be normally distributed, as described in the previous section, around a mean of (0.1)x(X1), or a difference of 26 accidents per year and have a standard deviation of 12.91 (ie. ((250/6+250/2)**0.5)). This assumes that the variance is constant for the pre and post-DRL data. With sample sizes of 6 and 2, the sample outcomes will be distributed as shown in Figure 20.

At the 95% confidence level, we would require an observed difference of 21 accidents per year (ie. 1.645x12.91). The probability of capturing this effect with our sample is equal to the shaded area as illustrated in Figure 20. Using the normal probability tables, we can say that this will happen with 65 percent probability. That is, if the magnitude of the DRL effect is 10 percent and the variability of accident levels per year is the same as in previous years, then we have a 65 percent chance of finding a significant change with a sample difference of means test. Further, if we reduce the significance level required from 95% to 90%, we can obtain about a 76 percent probability of observing a significant effect (however we increase the probability of a Type I error). Conversely, this says that there

FIGURE 19

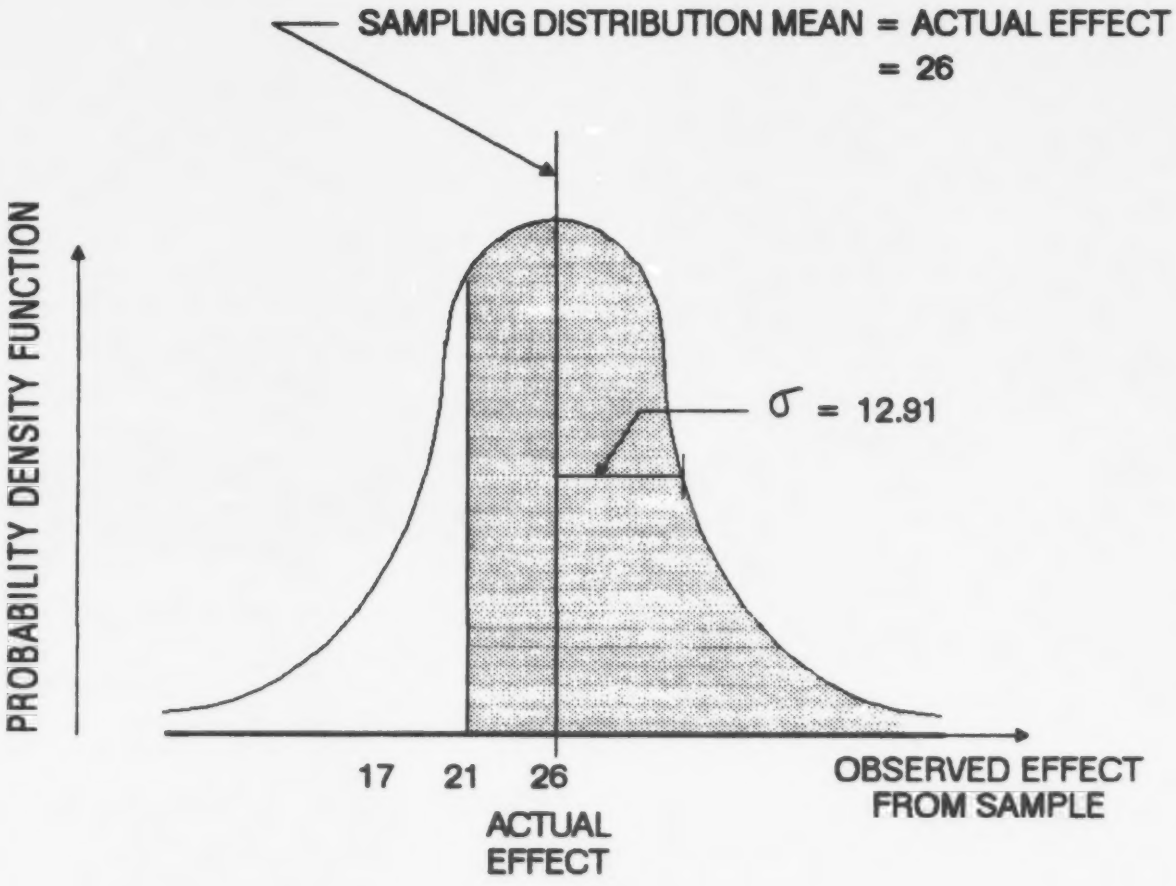
DISTRIBUTION FOR DIFFERENCES OF MEANS HYPOTHESIS TESTING



Z_α = FROM NORMAL PROBABILITY TABLES

$$Z_{ACTUAL} = \frac{\mu_1-\mu_2}{\sqrt{\frac{\sigma_1^2}{n_1}+\frac{\sigma_2^2}{n_2}}}$$

FIGURE 20
DISTRIBUTION OF SAMPLE OUTCOMES



$$Z = \frac{21 - 26}{12.91} = -0.39$$

$$F(Z = -0.39) = 0.15 + 0.50$$
$$= 0.65$$
$$= 65\ \%$$
$$= \text{SHADED AREA}$$

is a 24 percent chance of rejecting the hypothesis that there is a real DRL effect when the DRL effect is actually a 10 percent reduction in accidents.

Table 20 indicates the probability of obtaining a significant difference when the DRL effect varies between 5 percent and 20 percent, and where the required level of confidence varies between 5 percent and 10 percent.

TABLE 20

PROBABILITY OF OBSERVING SIGNIFICANT DIFFERENCES IN ACCIDENT LEVELS BEFORE AND AFTER DRL's ON CVA VEHICLES

Size of DRL effect	Level of Confidence 95%	90%
.05	0.27	0.38
.10	0.65	0.76
.15	0.92	0.96
.20	0.99	0.997

From the table it is apparent that for effects smaller than about 7 percent, this statistical procedure has a less than 50 percent power to discern the effect with statistical significance. Fortunately, the results of previous DRL experiments indicate that the DRL effect may be greater than 7 percent, so there is a reasonable chance that the CVA experiment will in fact reveal a significant result.

4.2.3 REGRESSION ANALYSIS

In the above, one of the limiting factors to the power of the test is the underlying variance in annual accident levels. One way to enhance the possibility of observing an effect at a significant level is to explain some of the variance with additional variables. For instance, the variance around the mean observed accident levels is about 250 accidents. These inter-year differences may be due to other causative factors such as differences in weather, average road speeds, traffic density, police surveillance and the fraction of cars with DRL's. (Even though DRL's were not enforced during this time, there may have been an increasing trend in the voluntary use of headlights.)

If reliable data could be obtained for each of the accidents in the sample then these explanatory variables could be applied in a statistical regression analysis to determine the contribution of each to the overall accident rate. A regression analysis can be

thought of as an extension of the differences of sample means approach to incorporate multiple explanatory variables. It's application requires many more basic assumptions about the statistical properties of the sample, but it provides a good way to incorporate the joint effect of many different variables. When regression analysis is being applied, the confounding influence of time trends can be accounted for directly.

The problem from this study design perspective is that first of all these data are not available for the historic accidents on a case by case basis. Second, there are statistical problems with using such data on a pooled basis for each year. Namely, there is a problem with aggregation bias, which means that some of the basic assumptions of the underlying regression procedure are violated, leading to biased estimates of parameters. More important to our study is a problem with degrees of freedom. If we were to use k explanatory variables to explain the accident levels in 8 different years, then we would have 8-k-1 degrees of freedom. Only very major effects can be detected at a significant level when there are so few degrees of freedom.

Given the difficulty in obtaining the appropriate values for the explanatory variables, even on an aggregate level, and the small sample size (ie. 8 years) regression analysis is of limited application in the context of this analysis. In spite of these limitations regression analysis was used in an attempt to remove time trends from some of the data (ie. accident costs), however without success. (See Appendix A for details).

4.3 RESULTS OF THE STATISTICAL TESTS

4.3.1 DIFFERENCE OF MEANS TESTS

The difference of means test, as described in the previous section, was conducted on the CVA accident data. The results of these tests are summarized in Table 21. Further details related to this test are included in Appendix B. A discussion of the results of the difference of means test is given below.

- The difference of means test was first performed on the number of multiple-vehicle daylight accidents with damages greater than $500, as presented in Table 19. It is observed from Table 21 that the average number of CVA multiple-vehicle daylight accidents post DRL's (ie. after DRL devices were installed, and presented as 1986 and 1987 data) was 11.6% lower than the same pre-DRL (ie. before DRL devices were installed, and presented as 1980 to 1985 data) data. The confidence level for the observed difference was 99.9%. That is, we are 99.9% confident that the observed means for pre and post-DRL data are statistically different.

- This decrease of 11.6% in multiple-vehicle daylight

TABLE 21

SUMMARY OF STATISTICAL ANALYSIS
DIFFERENCE OF MEANS TEST

VARIABLE	MEAN pre-DRL's	MEAN post-DRL's	DIFFERENCE Number	DIFFERENCE Percent	STATISTICAL SIGNIFICANCE OF DIFFERENCE
Multiple-Vehicle Daylight Accidents					
Total Number	260.2	230.0	30.2	11.6%	99.9%
By Severity:					
Property Damage	220.8	198.5	22.3	10.1%	99.9%
Personal Injury	37.3	31.0	6.3	16.9%	99.3%
Fatality	2.0	0.5	1.5	75.0%	93.7%
By Configuration:					
Right Angle (5)	79.5	60.5	19.0	23.9%	99.9%
Head on (7)	11.8	5.5	6.3	53.4%	99.9% *
Head on (8)	8.0	3.0	5.0	62.5%	99.9% *
Head on (9)	16.8	18.0	-1.2	-7.1%	72.2% *
Total (DRL affected)	116.2	87	29.2	25.1%	99.9%
Total (non-DRL affected)	144.0	143.0	1.0	0.7%	55.6%
Total Accident Cost	656,268	774,157	(117,889)	-18.0%	99.0%
Average Accident Cost	2526.5	3369.3	-842.8	-33.4%	99.9%
Other Accidents (All Single Vehicle and Multiple Vehicle darkness)	115.8	115.5	0.3	0.3%	51.2%

* NOTE: These number of observations are small (ie. less than 20-30) therefore the normal approximation for the difference of means test may be inappropriate. These results must therefore be interpreted with care.

accidents translates into an overall decrease in all types of accidents in the CVA fleet by 7.2% (ie. multiple-vehicle accidents account for 68.6% of accidents with damages greater than $500 and there are approximately 40 accidents per year that are reported but have less than $500 damages (after January 1, 1984)).

- There was a decrease in the number of accidents by severity in all three catagories. That is, property damage accidents, personal injury accidents, and fatality accidents all exhibited a decrease in the average number of accidents from the pre-DRL years to the post-DRL years. The most significant decrease was noted in the property damage accidents, where a 10.1% decrease was observed. The confidence level associated with this decrease was 99.9%. Personal injury accidents decreased by 16.9% (95.5% confidence level) and fatality accidents decreased by 75% (93.7% confidence level). The reason for the large percent decrease in the personal injury and fatality accidents and yet the lower confidence level is due to the small sample size (ie. the total number of each type of accident).

- The total number of accidents was broken down by accident configuration. Overall, those configurations in which the DRL's would have an effect (ie. would be expected to increase the visibility of the vehicle and hence decrease the probability of that particular type of accident) showed a decrease of 25.1 % from the pre-DRL to the post-DRL time periods. Statistically, there is >99.9% confidence that there was an actual decrease in the number of accidents. At the same time, those configurations in which the DRL's have no (theoretical) effect remained constant (an actual decrease of 0.7%). Individually, there was a decrease in three (ie. 5, 7 and 8) of the DRL-affected configurations. Configuration number 9 actually increased marginally, by 7.1%. The individual decreases were all statistically significant except for the increase in configuration number 9 which was not significant.

- Both the total accident cost and the average accident costs increase from the pre-DRL data to the post-DRL data. In general, this increase is due to the upward trend in the data, probably due to the higher costs associated with accident repairs. Because of the upward trend, a regression analysis was performed on the data. Details of this analysis are discussed in Appendix A.

- The difference of means test was conducted on those accidents which are not affected by the use of DRL's (ie. all single vehicle accidents and multiple-vehicle darkness accidents). A comparison of means pre and post-DRL installation indicated (essentially) a constant accident

level. That is, the number of non-DRL affected accidents remained constant (actually decreased by 0.3%) from the pre to the post-DRL period. The average number of non-DRL related accidents pre-DRL's was observed to be 115.8 accidents per year. The post-DRL accidents level was 115.5 accidents per year.

If DRL devices were extended to the total Saskatchewan vehicle fleet (800,000 vehicles) and had an 7.2 % decrease in the number of accidents, this would translate to a reduction of 2452 property damage accidents (ie. total number of property damage accidents of 34069 x 7.2%), 610 less injuries per year (ie. total personal injuries per year of 8465 x 7.2% decrease), and 15 fewer fatalities per year (ie. total fatalities of 214 per year x 7.2% decrease). (The data used in the calculations is from "1985 Saskatchewan Traffic Accident Facts" published by Saskatchewan Highways and Transportation.)

Caution needs to be exercised in extrapolating the CVA fleet experience to the total Saskatchewan vehicle population. The CVA fleet is comprised of publicly owned vehicles, operated by government employees mainly during working hours. This type of exposure would not be the same as the total Saskatchewan vehicle population. The CVA fleet in a subset of the entire Saskatchewan vehicle population with specific characteristics. The above calculations are included to give only an order of magnitude estimate of the impact of the use of DRL's in the total vehicle fleet in Saskatchewan.

5.0 CONCLUSIONS AND RECOMMENDATIONS

The objective of this study was to evaluate the effectiveness of the use of daytime running lights on accident rates, accident severity and the value of accidents claims in the Central Vehicle Agency vehicle fleet. This objective was accomplished.

The analysis was conducted on accidents with total estimated damages of more than $500. This restriction was imposed on the analysis because on January 1, 1984, the definition of a reportable accident changed from one involving $200 damages to one involving $500 damages. To keep the data consistent from year to year, all accidents with damages of $500 and less were eliminated.

The results of the analysis indicate that daytime running lights have had a positive, statistically significant impact on multiple-vehicle daylight accidents in the CVA fleet. The results are summarized below.

1. The total number of multiple-vehicle daylight accidents decreased by 11.6% from the pre-DRL period (1980 to 1985) to the post-DRL period (1986 and 1987). This decrease was statistically significant at the 99.9% confidence level. This decrease in multiple-vehicle daylight accidents (multiple-vehicle accidents account for 68% of the total accidents) translates into a 7.9% decrease in the total number of CVA accidents with damages greater than $500.

2. Over the same period of time, the total number of non-DRL effected accidents, namely all single vehicle accidents and multiple-vehicle darkness accidents, remained relatively constant, actually decreasing by only 0.3%.

3. Multiple-vehicle daylight accidents were classified by severity into three groups: property damage, personal injury, and fatality. There was a decrease in all three categories. However, for personal injury and fatality accidents there was some problem with small sample size which decreased the significance of the results. The actual decrease in each category and the corresponding confidence level are:

    - property damage accidents decreased by 10.1% (99.9% confidence level),
    - personal injury accidents decreased by 16.9% (95.3% confidence level), and
    - fatality accidents decrease by 75% (93.7% confidence level).

4. The multiple-vehicle daylight accidents were also classified into two groups according to accident configuration; those that would be affected with the use of DRL's (DRL-affected) and those that would not be affected by the use of DRL's (non DRL-affected). Over the study period, the DRL-affected accidents decreased by 25.1% (99.9% confidence level) from the pre-DRL period to the post-DRL period. The same analysis for the non DRL-affected accidents showed only a 0.7% decrease.

5. The data on multiple-vehicle daylight accident costs (both total and average costs as estimated by police at the accident scene) showed an increase from the pre-DRL period to the post-DRL period, this despite the reduced accident numbers. This fact was attributable to a general increase in the cost of accident repairs.

The vehicles owned by the CVA have unique operating characteristics which must be considered when comparing the CVA accident experience to the total Saskatchewan vehicle population. Driver characteristics, time of operation, and location of operation must all be considered in any comparison.

REFERENCES

1. D.A. Attwood, "The Potential of Daytime Running Lights as A Vehicle Collision Countermeasure". Road Safety Unit, Road and Motor Vehicle Traffic Safety Branch, Transport Canada, 1981.

2. D.A. Attwood, "Daytime Running Lights Project II: Vehicle Detection as a Function of Headlight Use and Ambient Illumination". Road Safety Unit, Ministry of Transport, Report No. RSU 75/2, April 1975.

3. "A Study of Daytime Running Lights". Road Safety and Motor Vehicle Regulation Directorate, Transport Canada, June 1985.

4. K. Anderson, G. Nilson, "The Effects on Accidents of Compulsory Use of Running Lights during Daylight in Sweden". National Road and Traffic Research Institute, 1981.

5. K. Anderson, G. Nilson, M. Salusjarvi, "The Effect of Recommended and Compulsory Use of Vehicle Lighting on Road Accidents in Finland". National Road and Traffic Research Institute, Report No. 102, 1976.

6. H. Stein, "Fleet Experience with Daytime Running Lights in the United States". Insurance Institute for Highway Safety, June 1984.

7. Thomas D. Cook, Donald T. Campbell, "Quasi-Experimentation, Design & Analysis Issues for Field Settings 1979.

APPENDIX A

STATISTICAL TESTING
REGRESSION ANALYSIS

STATISTICAL TESTING USING REGRESSION ANALYSIS

In the regression analysis a simple linear regression with one explanatory variable (time) was used. The constants (a and b) in the straight line formula, $y = ax + b$, were determined using the method of least squares and the data from 1980 to 1985 only. Based on the variance in the data and the required confidence level, the confidence interval for the regression line was found. This interval was then used to determine the confidence interval for the 1986 and 1987 data. The confidence interval was then compared to the actual observed values for these years. If our actual observed value for the number of accidents was outside of this confidence interval, then it was concluded that there was a (statistical) difference in the number of accidents per year before and after the DRL devices were installed. If the actual value for the number of accidents per year fell inside of the confidence interval, it was concluded that, at the given confidence level, there was not a (statistical) difference in the data before and after DRL devices were installed.

It was observed when conducting the difference of means test that data on accident costs (both total and average) along with the DRL-affected configuration accident data exhibited trends over time. Therefore, a simple linear regression analysis was applied to these three sets of data, in an attempt to determine statistically significant differences in these trends (ie. pre and post-DRL accident differences). A summary of the results is given in Table B-1. Further details of the regression analysis are presented in the tables that follow.

Several observations are noted from the regression analysis.

- The regression line for total accident cost had an upward slope, increasing at a rate of $50,000 per year. The variable (time) could only explain 48% of the variability in the data. Neither the 1986 nor the 1987 data fell outside of the 90% confidence interval, therefore, the data for post-DRL experience does not reflect any significant differences from the pre-DRL experience. This conclusion is due in part to the high variance in the data and the small sample size.

- The regression line for average costs had an upward slope, increasing at a rate of $216 per year (ie. the average cost of an accident increased by $216 per year). The variable (time) used in the analysis explained 62% of the variance in the data. As with the total accident costs, both the 1986 and the 1987 actual average costs fell within the confidence interval, therefore the difference in the 1986 and 1987 data is not statistically significant.

- The regression line for the DRL-affected accident configuration data had a downward slope, with a decrease of 4.43 accidents per year. The actual observed values for the

1986 and 1987 data fell on the border of the 90% confidence interval. That is, the 90% confidence interval for 1986 accidents was 89.6 to 111.7 per year, while the actual recorded value was 91 accidents per year. The 90% confidence interval for 1987 data was 82.6 to 109.9 per year with an actual observed value of 83 accidents per year.

TABLE A-1

STATISTICAL TESTING - REGRESSION ANALYSIS
MULTIPLE VEHICLE DAYLIGHT ACCIDENTS WITH DAMAGES GREATER THAN $500

YEAR	TOTAL COST ($)	AVERAGE COST ($/acc.)	CONFIGURATION DRL EFFECTED (5,7,8,9)
pre-DRL's			
1980	441,258	1,671.4	129
1981	656,511	2,574.6	115
1982	739,218	2,531.6	125
1983	662,407	2,726.0	114
1984	598,131	2,411.8	112
1985	840,081	3,243.6	102
post-DRL's			
1986	790,193	3,292.5	91
1987	758,120	3,446.0	83
STATISTICS - LINEAR REGRESSION (y = ax + b)			
Coefficients			
a	-3,450,262	-15,310	481.5
b	49,776	216.2	-4.43
Standard Error of Estimate	0.69	0.79	-0.86
90% Confidence Interval			
1986 Data			
high	615,440	2,594	89.6
low	1,045,528	3,973	111.7
1987 Data			
high	614,734	3,647	82.6
low	1,145,786	4,352	109.9

TABLE A-2

STATISTICAL ANALYSIS
REGRESSION ANALYSIS ON MULTIPLE VEHICLE DAYLIGHT ACCIDENTS

1. AVERAGE COSTS

	COUNT	YEAR (X)	AVERAGE COST (Y)	X squared	Y squared	XY
	1	80	1671.4	6400	2793578	133712.0
	2	81	2574.6	6561	6628565	208542.6
	3	82	2531.6	6724	6408999	207591.2
	4	83	2726.0	6889	7431076	226258.0
	5	84	2411.8	7056	5816779	202591.2
	6	85	3243.6	7225	10520941	275706.0
	Mean	82.5				
SUMMATION		495	15159.0	40855.0	39599938	1254401

Linear Regression, $Y = aX + b$

a = -15310
b = 216.2

Correlation Coefficient, r

r = 0.79

Standard Error of Estimate, Se

Se = 347.4

95% Confidence Interval- for value of Y for a given Xo

For Xo = 86
Range for Y = 3283.2 + or - 897.8
= 2385.4 to 4181.0
Actual Y= 3292.5

For Xo = 87
Range for Y = 3499.4 + or - 1109.6
= 2389.8 to 4609.0
Actual Y= 3446

90% Confidence Interval- for value of Y for a given Xo

For Xo = 86
Range for Y = 3283.2 + or - 689.5
= 2593.7 to 3972.7
Actual Y= 3292.5

For Xo = 87
Range for Y = 3499.4 + or - 852.1
= 2647.2 to 4351.6
Actual Y= 3446

FORMULAS

$$a = \frac{(\Sigma y)(\Sigma x^2) - (\Sigma x)(\Sigma xy)}{n(\Sigma x^2) - (\Sigma x)^2}$$

$$b = \frac{n(\Sigma xy) - (\Sigma x)(\Sigma y)}{n(\Sigma x^2) - (\Sigma x)^2}$$

$$r = \frac{n(\Sigma xy) - (\Sigma x)(\Sigma y)}{\sqrt{n(\Sigma x^2) - (\Sigma x)^2}\ \sqrt{n(\Sigma y^2) - (\Sigma y)^2}}$$

$$S_e = \sqrt{\frac{\Sigma y^2 - a(\Sigma y) - b(\Sigma xy)}{n-2}}$$

CONFIDENCE INTERVAL

$$a + bX_o \pm t_{\alpha/2} \cdot S_e \cdot \sqrt{\frac{1}{n} + \frac{n(X_o - \bar{X})^2}{n(\Sigma x^2) - (\Sigma x)^2}}$$

TABLE A-3

2. TOTAL COSTS

	COUNT	YEAR (X)	AVERAGE COST (Y)	X squared	Y squared	XY
	1	80	441,258	6400	1.95E+11	3.53E+07
	2	81	656,511	6561	4.31E+11	5.32E+07
	3	82	739,218	6724	5.46E+11	6.06E+07
	4	83	662,407	6889	4.39E+11	5.50E+07
	5	84	598,131	7056	3.58E+11	5.02E+07
	6	85	840,081	7225	7.06E+11	7.14E+07
	Mean	82.5				
SUMMATION		495	3,937,606	40855.0	2.67E+12	3.26E+08

Linear Regression, $Y = aX + b$

$a =$ -3450262
$b =$ 49,776

Correlation Coefficient, r

$r =$ 0.69

Standard Error of Estimate, Se

$Se =$ 108,346

95% Confidence Interval- for value of Y for a given Xo

For Xo = 86
Range for Y = 830,484 + or - 280,001
= 550,483 to 1,110,485
Actual Y= 790,183

For Xo = 87
Range for Y = 880,260 + or - 346,056
= 534,204 to 1,226,317
Actual Y= 758,120

90% Confidence Interval- for value of Y for a given Xo

For Xo = 86
Range for Y = 830,484 + or - 215,044
= 615,440 to 1,045,528
Actual Y= 790,183

For Xo = 87
Range for Y = 880,260 + or - 265,528
= 614,734 to 1,145,786
Actual Y= 758,120

TABLE A-4

3. CONFIGURATION - DRL EFFECTED ACCIDENTS

	COUNT	YEAR (X)	AVERAGE COST (Y)	X squared	Y squared	XY
	1	80	129	6400	16641	10320.0
	2	81	115	6561	13225	9315.0
	3	82	125	6724	15625	10250.0
	4	83	114	6889	12996	9462.0
	5	84	112	7056	12544	9408.0
	6	85	102	7225	10404	8670.0
	Mean	82.5				
SUMMATION		495	697	40855.0	8.14E+04	5.74E+04

Linear Regression, $Y = aX + b$

$a =$ 481.52

$b =$ -4.43

Correlation Coefficient, r

$r =$ -0.86

Standard Error of Estimate, Se

$Se =$ 5.6

95% Confidence Interval- for value of Y for a given Xo

For Xo =	86			
Range for Y =		100.7	+ or -	14.4
=		86.3	to	115.0
Actual Y=	91			
For Xo =	87			
Range for Y =		96.2	+ or -	17.8
=		78.5	to	114.0
Actual Y=	83			

90% Confidence Interval- for value of Y for a given Xo

For Xo =	86			
Range for Y =		100.7	+ or -	11.0
=		89.6	to	111.7
Actual Y=	91			
For Xo =	87			
Range for Y =		96.2	+ or -	13.6
=		82.6	to	109.9
Actual Y=	83			

APPENDIX B

STATISTICAL TESTING
DIFFERENCE OF MEANS ANALYSIS

TABLE B-1

STATISTICAL ANALYSIS
DIFFERENCE OF MEANS TEST

YEAR	NUMBER OF MULTIPLE VEHICLE DAYLIGHT ACCIDENTS			NUMBER OF OTHER ACCIDENTS (INCLUDES SINGLE VEHICLE AND DARKNESS ACCIDEN		
PRE-DRL INSTALLATION ($\bar{X}_1$)						
1980	264	Total=	1561	121	Total=	695
1981	255			129		
1982	292	Mean= μ_1	260.2	120	Mean=	115.8
1983	243			111		
1984	248	Variance= σ_1^2	249.8	110	Variance=	69.1
1985	259	$n_1 = 6$		104		
POST-DRL INSTALLATION ($\bar{X}_2$)						
1986	240	Total=	460	123	Total=	231
1987	220			108		
		Mean= μ_2	230.0		Mean=	115.5
		Variance= σ_2^2	100.0		Variance=	56.3
		$n_2 = 2$				
STATISTICAL TESTING						
DIFFERENCE OF MEANS DISTRIBUTION ($\bar{X}_1 - \bar{X}_2$)						
$\sqrt{\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}}$	Mean = $(\mu_1 - \mu_2)$		30.2	Mean =		0.3
	Standard Deviation =		9.6	Standard Deviation =		6.3
	Z statistic = $\frac{(\mu_1 - \mu_2)}{\sigma_{new}}$		3.15	Z statistic =		0.05
THEREFORE:						
	% Decrease =		11.6%	% Decrease =		0.3%
	Confidence level =		99.9%	Confidence level =		51.2%

TABLE B-2

STATISTICAL ANALYSIS - DIFFERENCE OF MEANS TEST
MULTIPLE VEHICLE DAYLIGHT ACCIDENTS WITH DAMAGES GREATER THAN $500

YEAR	TOTAL NUMBER OF ACCIDENTS	TOTAL COST ($)	AVERAGE COST ($/acc.)	ACCIDENT SEVERITY			CONFIGURATION					
				PROP. DAMAGE	PERS INJURY	FATAL	RT ANGLE (5)	HEAD ON (7)	HEAD ON (8)	HEAD ON (9)	TOTAL DRL EFFECTED	NO DRL EFFECT (4,6,10,11
pre-DRL's												
1980	264	441,258	1,671.4	232	32	0	90	16	10	13	129	135
1981	255	656,511	2,574.6	213	42	0	83	10	4	18	115	140
1982	292	739,218	2,531.6	246	40	6	76	16	9	24	125	167
1983	243	652,407	2,726.0	202	38	3	69	12	11	22	114	129
1984	248	598,131	2,411.8	212	36	0	87	7	5	13	112	136
1985	259	840,081	3,243.6	220	36	3	72	10	9	11	102	157
post-DRL's												
1986	240	790,193	3,292.5	204	35	0	63	6	4	18	91	149
1987	220	758,120	3,446.0	193	26	1	58	5	2	18	83	137
STATISTICS												
Average												
pre-DRL's	260.2	656,268	2526.5	220.8	37.3	2.0	79.5	11.8	8.0	16.8	116.2	144.0
post-DRL's	230.0	774,157	3369.3	198.5	31.0	0.5	60.5	5.5	3.0	18.0	87.0	143.0
Variance												
pre-DRL's	249.8	1.51E+10	2.17E+05	208.8	10.2	5.0	59.6	10.8	6.7	23.8	77.8	180.7
post-DRL's	100.0	2.57E+08	5.89E+03	30.3	25.0	0.3	6.3	0.3	1.0	0.0	16.0	36.0
Difference of Means (pre - post)	30.2	(117,889)	-842.8	22.3	6.3	1.5	19.0	6.3	5.0	-1.2	29.2	1.0
Percent decrease	11.6%	-18.0%	-33.4%	10.1%	17.0%	75.0%	23.9%	53.5%	62.5%	-6.9%	25.1%	0.7%
Z statistic	3.15	-2.30	-4.26	3.16	1.68	1.53	5.26	4.56	3.94	-0.59	6.37	0.14
Confidence level for difference	99.9%	99.0%	99.9%	99.9%	95.3%	93.7%	99.9%	99.9%	99.9%	72.2%	99.9%	55.6%